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International Review of Standards and Labeling Programs for Distribution Transformers

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Disclaimer

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Foreword

The Bureau of Oceans and International Environmental and Scientific Affairs' (OES) Office of Environmental Quality and Transboundary Issues (EQT) at the Department of State (DOS) awarded a grant to the team consisting of CLASP, LBNL, and RIVER Consultores to implement an Energy Efficiency project in Chile. The DOS grant aims at developing and improving energy efficiency practices, policies, and technologies through 1) increasing energy efficiency in companies that have agreed to take part in voluntary clean production agreements through work that demonstrably reduces the companies' energy intensity and emissions; 2) implementing regional energy efficiency strategies to produce demonstrable results; 3) and/or working with the Chilean Ministry of Energy (MoE) to strengthen and implement policies and regulations, such as Chile's 2015 energy efficiency bill, to improve resource efficiency.

The project awarded to the team by DOS supports the current Standards and Labeling program from the MoE, which mainly focuses on household appliances and some industrial motors, to expand the coverage of its program to products not yet regulated under the current scope: *distribution transformers* (DT).

This initiative was designed to facilitate the implementation of new policies such as energy-efficiency standard and labeling programs for distribution transformers, which will promote more energy-efficient technologies in this critical sector.

The project is implemented through three main activities:

- Providing the economic, environmental, financial, and technical rationale for energy efficiency policies and related programs through rigorous empirical analysis of the Chilean DT market;
- Developing appropriate policies based on international best practices that will transform the Chilean market towards more efficient distribution transformers; and
- Engaging with utilities and industry in Chile to generate greater awareness of the benefits of more efficient policies for DTs, and potential deployment of high efficiency distribution transformers.

In support of these activities, this report presents the current energy efficiency programs for distribution transformers around the world.

Abbreviations and Acronyms

ABNT	Brazilian Association of Technical Standards
AQSIQ	General Administration of Quality Supervision, Inspection and Quarantine
AS	Australian Standards
BEE	Bureau of Energy Efficiency, India
BIL	Basic-Impulse Insulation Level
BIS	Bureau of Indian Standards
CEA	Canadian Electricity Association
CEA	Central Electricity Authority
CECP	Centre for Energy Conservation Product
CEE	Consortium of Energy Efficiency
CNIS	China National Institute of Standardization
CQC	Quality Certification Centre
CRGO	Cold-Rolled, Grain-Oriented
DOE	United States Department of Energy
DOS	United States Department of State
DT	Distribution Transformers
E3	Equipment Energy Efficiency
ECCJ	Energy Conservation Centre, Japan
EN	European Norms
ENCE	National Energy Conservation Label
EPA	United States Environmental Protection Agency
EPACT	Energy Policy Act of 2005
EQT	Environmental Quality and Transboundary Issues
EU	European Union
GB	Guobiao
HEPS	Higher Energy Performance Levels
Hz	Hertz
ICONTEC	Instituto Colombiano de Normas Técnicas y Certificación
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IS	Indian Standards
ISI	Israeli Standards Institute
ISO	International Standards Organization
JIS	Japanese Industrial Standards
kV	Kilo Volt
kVA	Kilo Volt Amps
KS	Korean Standards
MEPS	Minimum Energy Performance Standards
MOIT	Ministry of Industry and Trade
MoE	Chilean Ministry of Energy
NDRC	National Development and Reform Commission
NEMA	National Electrical Manufacturer's Association
NOM	Norma Mexicana
NRCAN	Natural Resources Canada

NTP	Norma Técnica Peruana
NZS	New Zealand Standards
OES	Oceans and International Environmental and Scientific Affairs
PEI	Peak Efficiency Index
Pk	Coil Loss
PNTP	Proyecto de Norma Técnica Peruana
Po	Core Loss
PPEE	National Program for Energy Efficiency
S&L	Standards and Labeling
SEAD	Super-Efficient Equipment and Appliance Deployment Initiative
SWER	Single-Wire Earth Return
T&D	Transmission and Distribution
TCVN	Tiêu chuẩn Việt Nam
TEPS	Target Energy Performance Standard
US	United States
W	Watts

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Executive Summary

Transmission and distribution (T&D) losses in electricity networks represent 8.5% of final energy consumption in the world. In Latin America, T&D losses range between 6% and 20% of final energy consumption, and represent 7% in Chile. Because approximately one-third of T&D losses take place in distribution transformers alone, there is significant potential to save energy and reduce costs and carbon emissions through policy intervention to increase distribution transformer efficiency.

A large number of economies around the world have recognized the significant impact of addressing distribution losses and have implemented policies to support market transformation towards more efficient distribution transformers. As a result, there is considerable international experience to be shared and leveraged to inform countries interested in reducing distribution losses through policy intervention.

The report builds upon past international studies of standards and labeling (S&L) programs for distribution transformers to present the current energy efficiency programs for distribution transformers around the world. The report is organized under two sections. The first section of the report provides a summary of findings with a cross-cutting analysis of the energy efficiency policies that have been collected, focusing on four major aspects of policy design:

- Scope of regulation,
- Test standards,
- Energy efficiency policy types for distribution transformers,
- Efficiency metrics.

The second section of the report provides detailed, individual country profiles and web links for further information.

The following presents a summary of the report's findings.

Scope Comparison

The energy-efficiency policies for distribution transformers define their scope of coverage by making reference to:

- Insulation type (i.e., liquid-filled and dry-type)
- Number of phases (i.e., single-phase and three-phase)
- Range of kVA ratings (i.e., transformer capacity)
- Possible additional distinctions based on voltages (i.e., primary and/or secondary voltages)
- Possible additional distinctions on materials (i.e., silicon and amorphous cores)

Most economies that have policies or programs promoting energy-efficient distribution transformers will have requirements that apply to liquid-filled distribution transformers. The economies that have more comprehensive programs will set requirements for both liquid-filled and dry-type. And although dry-type distribution transformers are used around the world, they tend not to be the first type of distribution transformer covered and regulated.

Test Standards Comparison

Our comparison of the two reference test standards (for the IEC and IEEE family) found significant differences in definitions of kilovolt-ampere (kVA) and efficiency. Values for reference temperature, loss tolerances, and test conditions also differ between the standards. This makes it difficult to directly compare models tested with one standard to models compliant with the other standard.

IEC and IEEE have recognized the need for harmonization, as well as the benefits and challenges of a harmonized standard. As a result, the two organizations have initiated a “dual-logo” process in which working groups of interested stakeholders collaborate to establish common standards that carry the IEC/IEEE logo. When a standard carries the "Dual" IEC/IEEE logo, it is a "Unified" standard making it a truly global standard. To date, more than 23 dual-logo standards have been developed in various fields including design automation, dielectrics, instrumentation, transformers, etc. There are two dual-logo standards for transformers, but neither applies to distribution transformers:

- IEC 60076-21 Ed. 1 (2011-12) (IEEE Std C57.15™-2009 Power Transformers - Part 21: Standard Requirements, Terminology, and Test Code for Step-Voltage Regulators
- IEC 62032 Ed.1 (2005-03) (IEEE C57.135™-2001): Guide for the Application, Specification and Testing of Phase-Shifting Transformer

Energy efficiency policy types for distribution transformers

Our review of energy efficiency policies for distribution transformers finds 15 countries with programs covering distribution transformers around the world. The review finds that energy efficiency standards (also referred to as Minimum Energy Performance Standards or MEPS) and labeling programs are the most common policies used to regulate distribution transformers. As it is the case for other MEPS and labeling programs for appliances and equipment, the review finds that countries that have adopted a MEPS for distribution transformers also have a program that identifies higher efficiency distribution transformers on the market.

Efficiency performance metrics

The energy performance metric is a key element of the formulation of energy efficiency programs. Our research identifies four different ways to define the energy performance of a distribution transformer, with their pros and cons, as presented in the following table:

Table ES 1 - Pros and Cons of Energy Performance Metrics

Energy Performance Metric	Pros	Cons
Maximum no-load (NLL) and load-losses (LL) (W)	-Doesn’t require the specification of a loading point -Commonly used in procurement practices	-Restricts technological / design flexibility
Maximum combined losses at a specified loading point (W)	-Combines NLL and LL in one metric providing maximum technological / design flexibility -Enables cost optimized designs	-Requires a specific loading point
Efficiency percentage (%)	-Combines NLL and LL in one metric providing maximum technological / design flexibility -Enables cost optimized designs	-Requires a specific loading point
Peak Efficiency Index (PEI) (%)	-Doesn’t require the specification of a loading point in regulation	-Has not been used in regulation for distribution transformer (only power transformers)

Introduction

Transmission and distribution (T&D) losses in electricity networks represent 8.5% of final energy consumption in the world. In Latin America, T&D losses range between 6% and 20% of final energy consumption, and represent 7% in Chile. Because approximately one-third of T&D losses take place in distribution transformers alone, there is significant potential to save energy and reduce costs and carbon emissions through policy intervention to increase distribution transformer efficiency.

According to past studies from Lawrence Berkeley National Laboratory (LBNL), 132 TWh savings could be achieved in five major economies around the world with the adoption of the most efficient current transformer designs, thereby avoiding 84 Mt of CO_2 emissions in 2030 (Letschert et al. 2012). The cost-effective savings potentials were estimated to be about 65% of the technical potential at 86 TWh in 2030 (46 $MtCO_2$). In the APEC region alone (excluding China), LBNL identified 30 TWh of cost-effective savings achievable by 2030, representing a reduction of 19% in network losses in the region and a reduction of 17 $MtCO_2$ in the same year (Letschert et al., 2013).

A large number of economies around the world have recognized the significant impact of addressing distribution losses and have implemented policies to support market transformation towards more efficient distribution transformers. As a result, there is considerable international experience to be shared and leveraged to inform countries interested in reducing distribution losses through policy intervention.

The goal of this report is to present the current energy efficiency programs for distribution transformers around the world. The report is organized under two sections. The first section of the report provides a summary of findings with a cross-cutting analysis of the energy efficiency policies that have been collected, focusing on four major aspects of policy design:

- Scope of regulation,
- Test standards,
- Energy efficiency policy types for distribution transformers,
- Efficiency metrics.

The second section of the report provides detailed, individual country profiles and web links for further information.

The report builds upon past international studies of S&L programs for distribution transformers that have been published by the Super-efficient Equipment and Appliance Deployment (SEAD) initiative (SEAD, 2013a; SEAD, 2013b; SEAD, 2013c; SEAD, 2013d) and the International Copper Association (ICA) (Letschert et al., 2013; Waide and N14 Energy, 2014) and provide updated information when available.

Summary of findings

This section looks across the individual country profiles and provides a crosscutting analysis of the three sub-sections presented in each country profiles: scope, test standard, and energy efficiency policies for distribution transformers. In addition, this section also presents analysis of the energy performance metric, a key element of the formulation of energy efficiency policies for distribution transformers.

Scope

The energy-efficiency policies for distribution transformers define their scope of coverage by making reference to:

- Insulation type (i.e., liquid-filled and dry-type)
- Number of phases (i.e., single-phase and three-phase)
- Range of kVA ratings (i.e., transformer capacity)
- Possible additional distinctions based on voltages (i.e., primary and/or secondary voltages)
- Possible additional distinctions on materials (i.e., silicon and amorphous cores)

Most economies that have policies or programs promoting energy-efficient distribution transformers will have requirements that apply to liquid-filled distribution transformers. The economies that have more comprehensive programs will set requirements for both liquid-filled and dry-type. And although dry-type distribution transformers are used around the world, they tend not to be the first type of distribution transformer covered and regulated. Figure 1 presents a map illustrating energy efficiency programs that were assessed for this study, considering liquid-filled and dry-type distribution transformers.

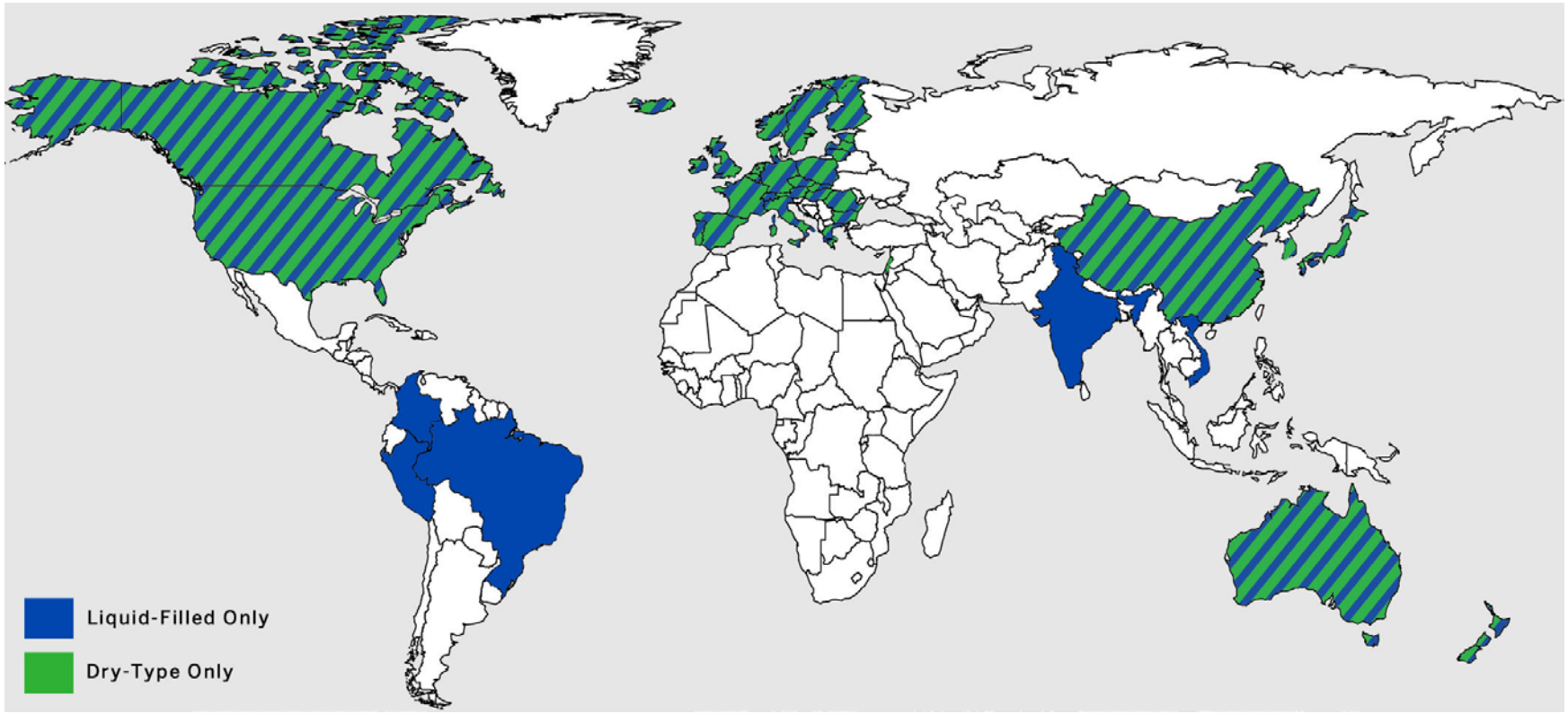

Figure 1 - Scope of International Energy Efficiency Programs for Distribution Transformers

Test Standard

The review of country standards shows that all of the test standards are derived from either the IEC 60076 or IEEE C57.12 family of standards. There are some minor local modifications to these standards, but, for the most part, the economies use the standards as written. In the review, we found that three economies use IEEE standards: Canada, Chile, and the United States, while all the other countries with energy-efficiency policies in place for distribution transformers refer to IEC standards. The figure on the following page summarizes our findings.

The following section provides a comparison of the IEC and IEEE testing standards for distribution transformers, building upon the LBNL study for APEC (Letschert et al., 2013b) and part 3 of the SEAD study (SEAD, 2013b).

The IEC 60076 family of standards is composed of 19 parts. The review focuses on:

- Part 1: General

The IEEE standard has over 90 standards and guides in the C57.12 family of standards. The review focused on:

- C57.12.00: General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

The comparison of the two reference standards is organized around the four elements that have the greatest effect on determining transformer efficiency:

1. General test condition requirements
2. No-load loss (NLL) test
3. Load-loss (LL) test
4. Calculation of efficiency

The tables in Annex I present a detailed comparison of the two standards along with the specific clauses that have been analyzed.

Our comparison of the two standards found significant differences in definitions of kilovolt-ampere (kVA) and efficiency. Values for reference temperature, loss tolerances, and test conditions also differ between the standards. This makes it difficult to directly compare models tested with one standard to models compliant with the other standard.

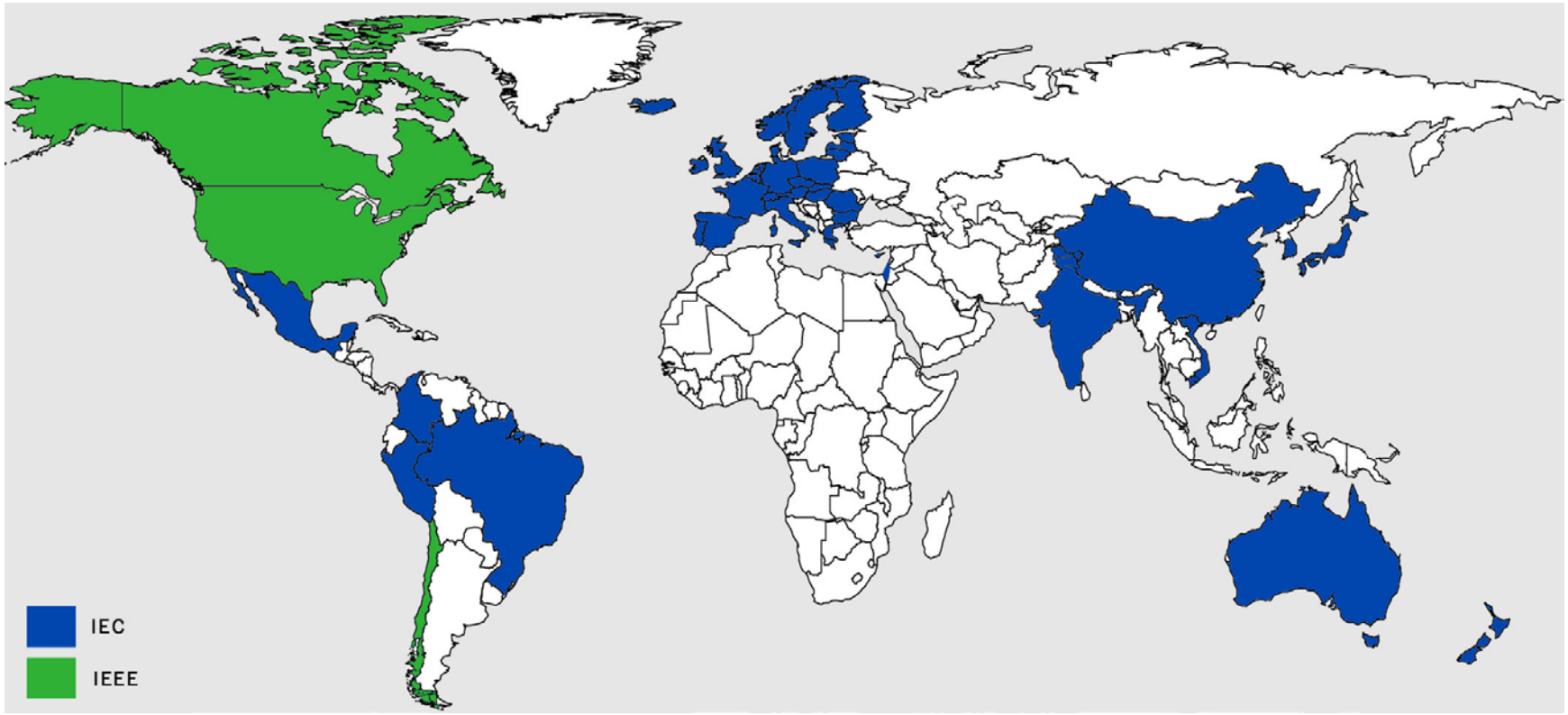

Figure 2 - Reference Test standard in Energy Efficiency Programs for Distribution Transformers

IEC and IEEE have recognized the need for harmonization, as well as the benefits and challenges of a harmonized standard. As a result, the two organizations have initiated a "dual-logo" process in which working groups of interested stakeholders collaborate to establish common standards that carry the IEC/IEEE logo[1]. When a standard carries the "Dual" IEC/IEEE logo, it is a "Unified" standard making it a truly global standard. To date, more than 23 dual-logo standards have been developed in various fields including design automation, dielectrics, instrumentation, nuclear power, switchgears, and transformers. There are two dual-logo standards for transformers, but neither applies to distribution transformers:

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- IEC 62032 Ed.1 (2005-03) (IEEE C57.135™-2001): Guide for the Application, Specification and Testing of Phase-Shifting Transformer

Energy Efficiency Policies

Our review of energy efficiency policies for distribution transformers found 15 countries with programs covering distribution transformers around the world. The review finds that energy efficiency standards (also referred to as Minimum Energy Performance Standards or MEPS) and labeling programs are the most common policies used to regulate distribution transformers. As it is the case for other MEPS and labeling programs for appliances and equipment, the review finds that countries that have adopted a MEPS for distribution transformers also have a program that identifies higher efficiency distribution transformers on the market, namely:

- Comparative labeling program: Brazil, India
- Endorsement label: US, China, Japan
- High Efficiency Performance Standards (HEPS): Australia, New Zealand and Korea

Some countries such as Chile, Colombia, Peru, and Israel have adopted voluntary standards as a first step in regulating DTs. In the case of Chile, this project will build upon these past efforts in order to support the development of a mandatory standard accompanied by a complementary labeling program.

Figure 3 provides an illustration of the type of S&L programs found in our international review.

[1] More information is available at http://standards.ieee.org/develop/intl/iec.html

Figure 3 – Standards and Labeling Programs for Distribution Transformers

The study commissioned by SEAD in 2013 provided a comparison of the relative stringency of selected requirements defined in MEPS, HEPS, and other programs around the world (SEAD, 2013a). The methodology takes into account the differences in test standards, efficiency metrics (see following section for discussion), and frequency of operation, aligning the international standards requirements with the IEC definition, with efficiency rated at 50% load and 50Hz frequency of operation in order to provide a global comparison of programs.

The following figures illustrate the findings from the SEAD study, with slight updates reflecting additional country programs or updated programs.

Figure 4 and Figure 5 present a comparison of the various programs for liquid-filled three-phase distribution transformers. Figure 4 shows mandatory and voluntary MEPS requirements, while Figure 5 presents high efficiency targets found in some of the country programs, such as HEPS, India 5 star energy label, China Grade 1 efficiency requirement, upcoming US and EU MEPS etc.; in comparison with the best available technology (Max Tech) identified as part of the US rulemaking (USDOE, 2013).

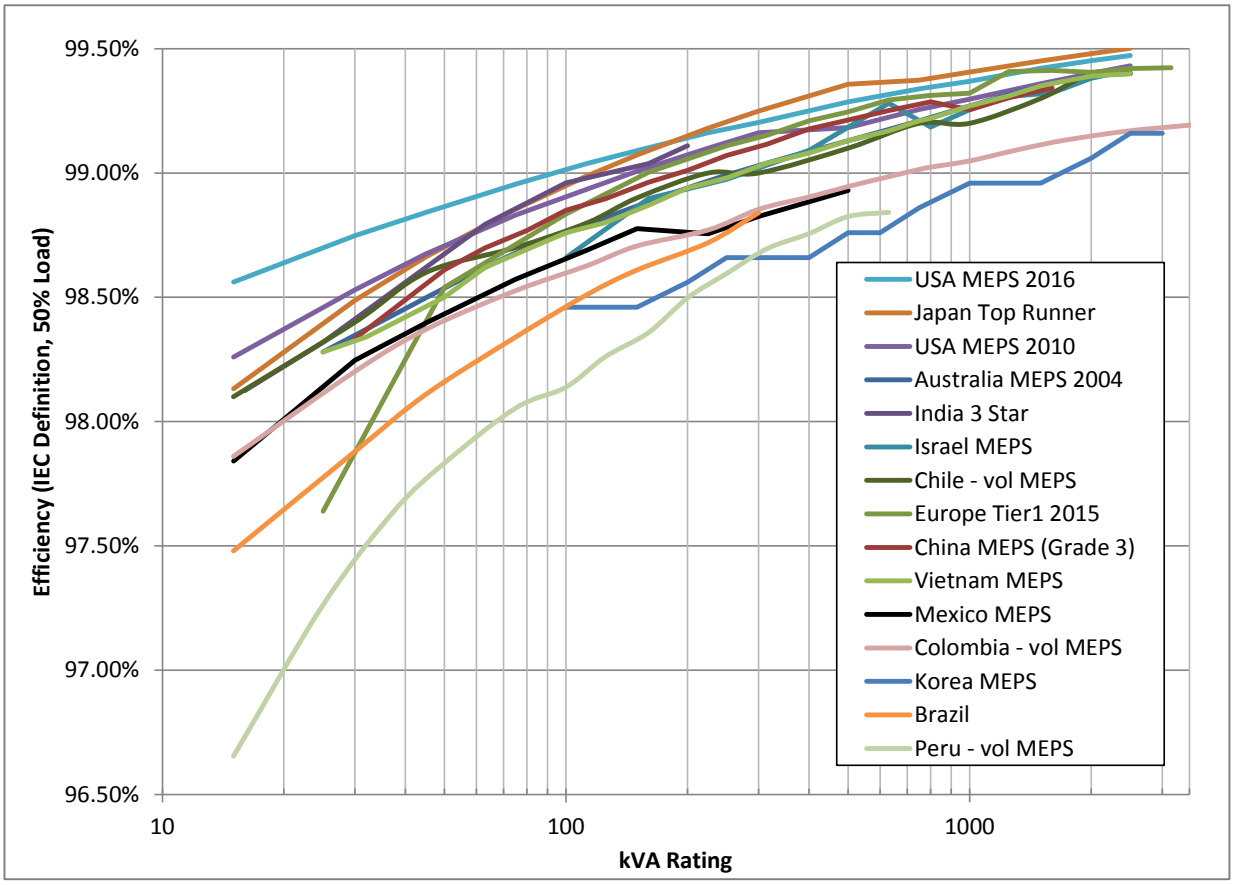

Figure 4 - Efficiency at 50% Load for MEPS Requirements on Three-Phase Liquid-Filled

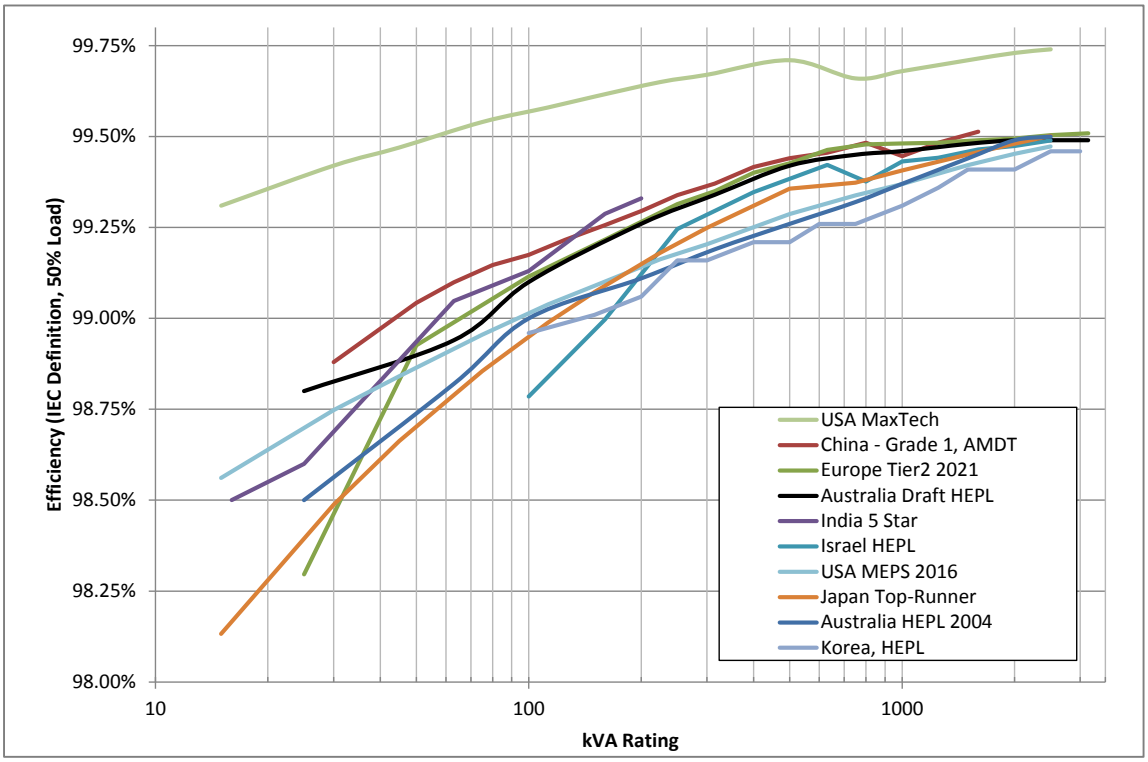

Figure 5 - High Efficiency at 50% Load for Three-Phase Liquid-Filled

Figure 6 presents a comparison of the various programs for liquid-filled single-phase distribution transformers, combining existing MEPS and high efficiency requirements.

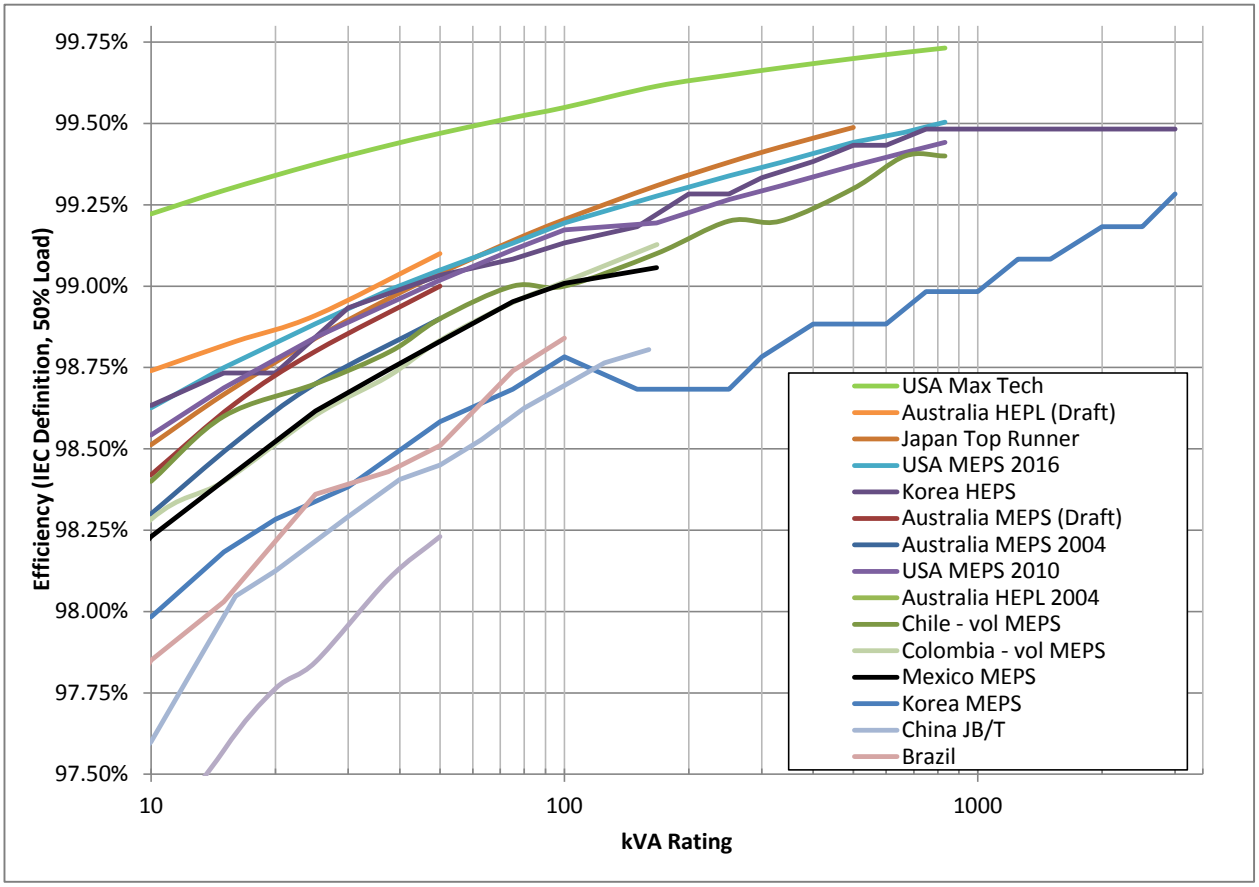

Figure 6 - Efficiency and High Efficiency Requirements at 50% Load for Single-Phase Liquid-Filled

Figure 7 and Figure 8 below offer a comparison of programs reviewed for medium-voltage dry-type distribution transformers. Figure 7 shows mandatory and voluntary MEPS requirements, while Figure 8 presents high efficiency targets found in some of the country programs, such as HEPS, China Grade 1 efficiency requirement, upcoming US and EU MEPS etc.; in comparison with the best available technology (Max Tech) identified as part of the US rulemaking (USDOE, 2013).

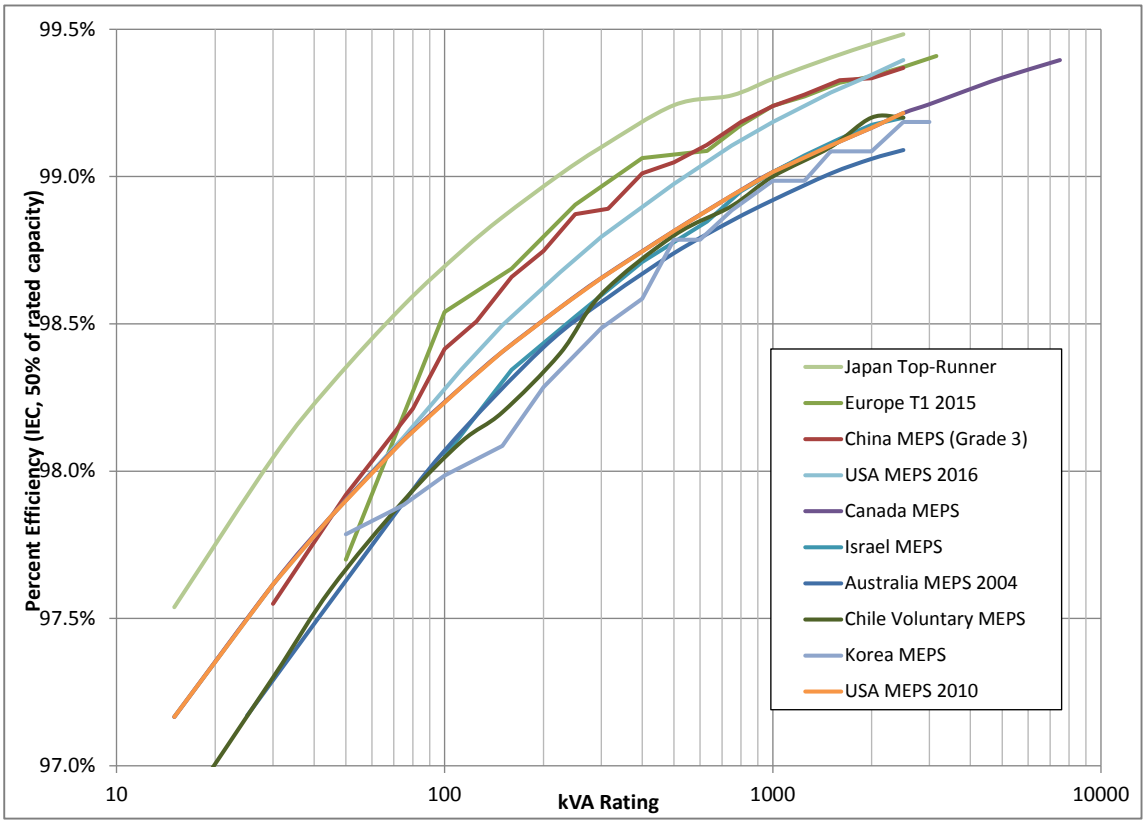

Figure 7 - Efficiency at 50% Load for Three-Phase Dry -type

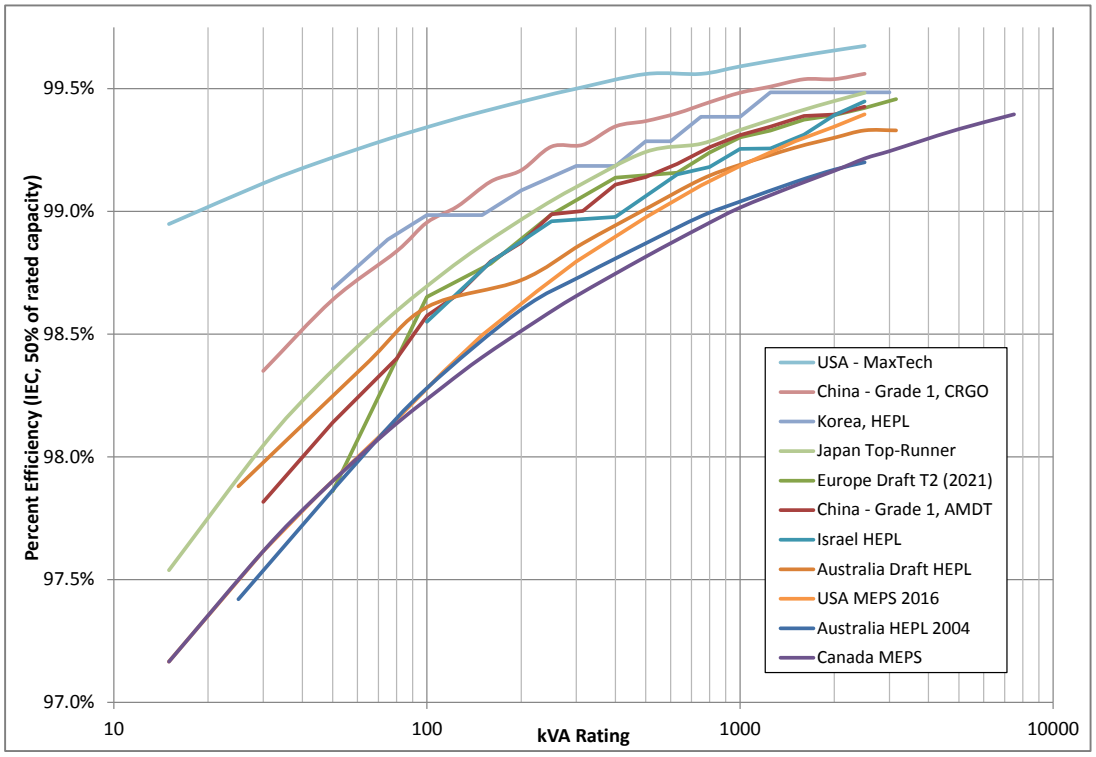

Figure 8 – High Efficiency at 50% Load for Three-Phase Dry -type

Energy Performance Metric

The energy performance metric is a key element of the formulation of energy efficiency programs. Our research identified four different ways to define the energy performance of a distribution transformer:

-Maximum no-load and load-losses: this metric defines two design constraints on each transformer and is closest to that specified in the common test standards. Unless noted otherwise, Maximum load-losses are measured at full load.
-Maximum combined losses: this metric defines a single constraint on the sum of the no-load losses and the load losses at a specified loading point, allowing design trade-offs between core losses and winding losses.
-Minimum efficiency requirements: this metric is a percentage value, representing the active power in watts delivered by the transformer to the load relative to the active power in watts drawn by it from the source. Percent efficiency must be declared at a specified loading point (50% in most cases).
-Peak Efficiency Index (PEI): peak efficiency represents the highest efficiency value of any transformer design, irrespective of a specified loading point.

The following map illustrates summarizes our findings.

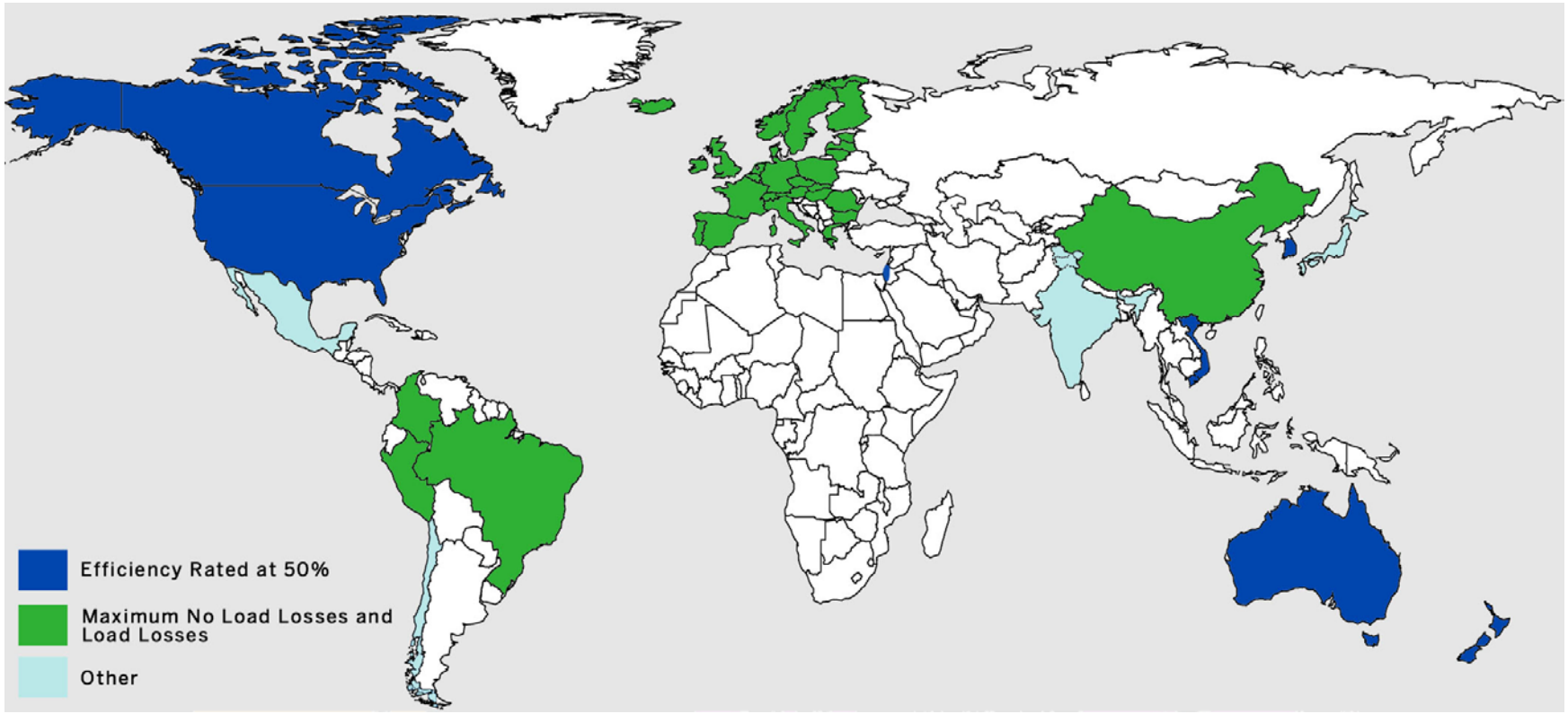

Figure 9 -Energy Performance Metric defined in S&L Programs for Distribution Transformers

These different approaches have been discussed in great detail in the SEAD study (SEAD, 2013b) and a more recent study for the ICA (Waide and N14 Energy, 2014). The following table summarizes the advantages and disadvantages of each approach.

Table 1 - Pros and Cons of Energy Performance Metrics

Energy Performance Metric	Pros	Cons
Maximum no-load and load-losses	-Doesn't require the specification of a loading point -Commonly used in procurement practices	-Restricts technological / design flexibility
Maximum combined losses at a specified loading point	-Combines NLL and LL in one metric providing maximum technological / design flexibility -Enables cost optimized designs	-Requires a specific loading point
Efficiency percentage	-Combines NLL and LL in one metric providing maximum technological / design flexibility -Enables cost optimized designs	-Requires a specific loading point
PEI	-Doesn't require the specification of a loading point in regulation	-Has not been used in regulation for distribution transformer (only power transformers)

Note: Maximum combined losses and Efficiency percentage are equivalent metrics, for a given loading point, as they are related by the DT capacity.

In addition to the efficiency metrics presented in the table, a slightly new approach has been proposed by the U.S EPA in the first draft of Energy Star specifications (currently under review by stakeholders). The draft considers defining minimum efficiency requirements at different load factors (between 10% and 70%) in order to qualify for the Energy Star label – instead of 50% as usually required. More information about the Energy Star program is available in the U.S. country section of this report.

Finally, an IEC Technical Committee is preparing part 20 of the IEC 60076 standard that will focus on energy efficiency. This document will address the different metric issue by integrating three scenarios: (1) load losses / no load losses; (2) efficiency at 50% load; (3) peak efficiency index. At this time, the work on this document is still on going, however drafts released indicate that it will be adopting the European regulatory measure as an IEC guidance document (i.e., not a design standard).

Summary Table

Lastly, the following table summarizes the results of the findings for countries/region with S&L programs, presenting reference test procedure, energy performance metric, and type of programs/scope.

Table 2 - Summary of Findings for Countries with S&L Programs

Country or region	Reference test procedure	Energy performance index	Type of S&L programs
Australia/New Zealand	IEC	Efficiency at 50% Load	Mandatory MEPS and HEPS
Brazil	IEC	No-Load and Max Total Load Losses	MEPS and Labeling program
Canada	IEEE	Efficiency at 50% Load	Mandatory MEPS for dry type
			Voluntary for liquid filled
Chile	IEEE	Efficiency at 50% Load	Voluntary MEPS
China	IEC	No-Load and Load Losses	Mandatory MEPS and Labeling program
Colombia	IEC	Losses at 100% Load	Voluntary MEPS
European Union	IEC	No-Load and Load Losses	Mandatory MEPS
		Capacity ≥ 3150 kVA: PEI	
India	IEC	Losses at 100% Load and at 50% Load	Mandatory MEPS and Labeling program
Israel	IEC	Efficiency at 50% Load	Voluntary MEPS
Japan	IEC	Total Losses at 40% or 50% Load	Mandatory MEPS and Labeling program
Korea	IEC	Efficiency at 50% Load	Mandatory MEPS and HEPS
Mexico	IEEE	Efficiency at 80% Load	Mandatory MEPS for liquid filled
Peru	IEC	No-Load and Load Losses	Voluntary MEPS for liquid filled
USA	IEEE	Efficiency at 50% Load	Mandatory MEPS and labeling
Vietnam	IEC	Efficiency at 50% Load	Mandatory MEPS

Country Policy Measures for Distribution Transformers

This section presents country summaries of scope of coverage, test standards, and energy-efficiency standards and labeling programs for policy measures focused on distribution transformers. This section builds upon recent reports (SEAD, 2013d; LBNL, 2013; Waide and N14 Energy, 2014), providing updates or additional information for the following countries: Brazil, Chile, China, Colombia, EU, India, Korea, Mexico, Peru, US, and Vietnam.

Commonwealth of Australia and New Zealand

Scope of Coverage

Since 2004, the Australian and New Zealand governments established minimum energy performance standards (MEPS) to regulate the following distribution transformers: single- and three-phase, dry-type and liquid-filled, with power ratings between 10 kVA and 2,500 kVA and which are designed for 11-kV and 22-kV networks. The current MEPS for transformer efficiency are defined in Australian Standard (AS) 2374.1.2-2003 at a rated load of 50%. AS 2374.1.2-2003 also identifies voluntary higher energy performance levels (HEPS) as aspirational targets. The MEPS also defines devices that are exempt from the regulation, such as instrument transformers, auto transformers, and traction transformers mounted on rolling stock, etc. New Zealand has harmonized with the Australian Standards.

Test Standard

The test standard for the MEPS is designated in the AS 2374.1.2-2003. Although there is no designated test standard developed specifically for the efficiency requirements, the test standard is based on the power loss measurement techniques specified in the Australian/New Zealand power transformer Standard AS/NZS 60076.1, which is adopted from the IEC Standard IEC 60076 - Power Transformers, Part 1: General. The test standard includes variations applicable to Australia, such as commonly used power ratings and preferred methods of cooling, connections in general use, and details of connection designation.

Energy Efficient Distribution Transformer Policies

The equipment energy efficiency (E3) program is currently in the process of reviewing the MEPS for distribution transformers, considering a possible increase of the MEPS levels to approximately the same as current HEPS levels as well as a possible expansion of the scope to include 33-kV networks (wind farms) and larger distribution transformers up to 3,150 kVA. More information about Australia and New Zealand standards and labeling program is available at: www.energyrating.gov.au and http://www.eeca.govt.nz.

Table 3 presents the requirements for liquid-filled distribution transformers for MEPS and HEPS along with the proposed revision. Note the similarities between the proposed MEPS2 and the 2004 HEPS, with a slight deviation in efficiency at the larger three-phase kVA ratings.

Table 3 – MEPS and HEPS Requirements and Proposed Revisions for Liquid-Filled Distribution Transformers in Australia and New Zealand

Liquid-Filled 50 Hz	kVA	Efficiency at 50% Loading			
		2004 MEPS	MEPS2 (proposed)	2004 HEPS	HEPS2 (proposed)
Single phase (and SWER[2])	10	98.30	98.42	98.42	98.74
	16	98.52	98.64	98.64	98.83
	25	98.70	98.80	98.80	98.91
	50	98.90	99.00	99.00	99.10
Three phase	25	98.28	98.50	98.50	98.80
	63	98.62	98.82	98.82	98.94
	100	98.76	99.00	99.00	99.10
	200	98.94	99.11	99.11	99.26
	315	99.04	99.19	99.19	99.34
	500	99.13	99.26	99.26	99.42
	750	99.21	99.32	99.32	99.45
	1,000	99.27	99.37	99.37	99.46
	1,500	99.35	99.40	99.44	99.48
	2,000	99.39	99.40	99.49	99.49
	2,500	99.40	99.40	99.50	99.49
	3,150	n/a	99.40	n/a	99.49

Note: For intermediate power ratings, the power efficiency level shall be calculated by linear interpolation.

[2] Single-wire earth return (SWER) or single-wire ground return is a single-wire transmission line for supplying single-phase electrical power from an electrical grid to remote areas at low cost. Its distinguishing feature is that the earth (or sometimes a body of water) is used as the return path for the current, to avoid the need for a second wire (or neutral wire) to act as a return path.

Table 4 and Table 5 present the MEPS and HEPS, and their proposed revision, for dry-type transformers in Australia and New Zealand. The regulation applies to dry-type transformers with the high voltage winding (Um) of 12kV and 22kV. As part of the current review of transformers standards, it is proposed to add requirements for a higher voltage class, Um=36kV within the standard.

Table 4 - MEPS Requirements and Proposed new MEPS for Dry-Type Distribution Transformers in Australia and New Zealand

Dry-type 50 Hz	kVA	Efficiency at 50% Loading					
		Um*=12kV		Um=24kV		Um=36kV	
		Current MEPS	MEPS2 (proposed)	Current MEPS	MEPS2 (proposed)	Current MEPS	MEPS2 (proposed)
Single phase (and SWER)	10	97.29	97.53	97.01	97.32	-	96.87
	16	97.60	98.83	97.27	97.55	-	97.11
	25	97.89	98.11	97.53	97.78	-	97.37
	50	98.31	98.50	97.91	98.10	-	97.74
Three phase	25	97.17	97.42	97.17	97.42	-	96.92
	63	97.78	98.01	97.78	98.01	-	97.30
	100	98.07	98.28	98.07	98.28	-	97.58
	200	98.46	98.64	98.42	98.60	-	98.26
	315	98.67	98.82	98.59	98.74	-	98.44
	500	98.84	98.97	98.74	98.87	-	98.62
	750	98.96	99.08	98.85	98.98	-	98.77
	1,000	99.03	99.14	98.92	99.04	-	98.87
	1,500	99.12	99.21	99.01	99.12	-	98.99
	2,000	99.16	99.24	99.06	99.17	-	99.00
	2,500	99.19	99.27	99.09	99.20	-	99.00
	3,150	-	99.27	-	99.20	-	99.00

Note: For intermediate power ratings, the power efficiency level shall be calculated by linear interpolation.

Table 5 - HEPS and Proposed new HEPS for Dry-Type Transformers in Australia and New Zealand

Dry-type 50 Hz	kVA	Efficiency at 50% Loading					
		Um=12kV		Um=24kV		Um=36kV	
		Current HEPS	HEPS2 (proposed)	Current HEPS	HEPS2 (proposed)	Current HEPS	HEPS2 (proposed)
Single phase (and SWER)	10	97.53	98.20	97.32	97.90	-	97.50
	16	97.83	98.32	97.55	98.06	-	97.75
	25	98.11	98.48	97.78	98.20	-	97.98
	50	98.50	98.78	98.10	98.50	-	98.33
Three phase	25	97.42	97.88	97.42	97.88	-	97.55
	63	98.01	98.37	98.01	98.37	-	97.96
	100	98.28	98.61	98.28	98.61	-	98.25
	200	98.64	98.83	98.60	98.72	-	98.51
	315	98.82	98.95	98.74	98.87	-	98.63
	500	98.97	99.08	98.87	99.01	-	98.79
	750	99.08	99.19	98.98	99.13	-	98.91
	1,000	99.14	99.26	98.04	99.19	-	98.99
	1,500	99.21	99.33	99.12	99.26	-	99.08
	2,000	99.24	99.37	99.17	99.30	-	99.14
	2,500	99.27	99.39	99.20	99.33	-	99.19
	3,150	-	99.39	-	99.33	-	99.19

Note: For intermediate power ratings, the power efficiency level shall be calculated by linear interpolation.

Federative Republic of Brazil

Scope of Coverage

For liquid-filled distribution transformers, Brazil has issued a mandatory MEPS requirement through an Inter-Ministerial Ordinance on energy labeling for distribution transformers from the Ministry of Mines and Energy. Brazil defined MEPS for single-phase liquid-filled distribution transformers from 5 to 100 kVA, with voltage classes of 15 kV, 24.2 kV and 36.2 kV, and three-phase liquid-filled distribution transformers from 15 to 300 kVA, with the same three voltage classes. Both of these requirements entered into effect in December 2014.

Test Standard

The Brazilian test standard for distribution transformers is published by the Brazilian Association of Technical Standards (ABNT): ABNT NBR 5440:2014. The test standard appears to be consistent with the loss measurement approach followed in the international standard, IEC 60076.1.

Energy Efficient Distribution Transformer Policies

For liquid-filled distribution transformers, Brazil has adopted MEPS requirements through the Inter-Ministerial Ordinance 104/2013, from the Ministry of Mines and Energy. This defined the maximum watts of energy consumption by voltage class and number of phases. More information about Brazil standards and labeling program is available at: www.inmetro.gov.br.

The following table presents the maximum losses associated with the current regulation for liquid-filled transformers in Brazil.

Table 6 - Brazil's MEPS for Liquid-Filled Distribution Transformers

kVA	15 kV		24.2 kV		36.2 kV	
	Max Core Loss (Watts)	Max Total Loss (Watts)	Max Core Loss (Watts)	Max Total Loss (Watts)	Max Core Loss (Watts)	Max Total Loss (Watts)
Single-Phase						
5	35	140	40	155	45	160
10	50	245	55	265	60	270
15	65	330	75	365	80	380
25	90	480	100	520	105	545
37.5	135	665	145	740	150	740
50	165	780	190	925	200	935
75	205	1,110	225	1,210	240	1,225
100	255	1,445	275	1,495	280	1,480
Three-Phase						
15	85	410	95	470	100	460
30	150	695	160	790	165	775
45	195	945	215	1055	230	1,075
75	295	1,395	315	1,550	320	1,580
112.5	390	1,890	425	2,085	440	2,055
150	485	2,335	520	2,610	540	2,640
225	650	3,260	725	3,605	750	3,600
300	810	4,060	850	4,400	900	4,450

In addition to the mandatory MEPS requirements, Brazil has also adopted a labeling program for liquid-filled distribution transformers. The objectives of these policy measures are to establish a maximum acceptable level of loss and to encourage the specification and purchasing of more energy-efficient liquid-filled distribution transformers, new and reconditioned.

The label is formatted in a specific way and applied to all transformers where it will be visible to the user, as defined by the national energy conservation label (ENCE), in compliance with Brazilian national law No 10.295/2001, concerning the National Policy for the conservation and rational use of energy. The labeling program for distribution transformers includes the manufacturer, model, type, kVA rating, and voltage class. The label also presents the watts of losses at no load and total watts of loss at full load, temperature rise and BIL (Basic-Impulse Insulation Level) of the transformer at both the nominal tap and the 'critical' tap (meaning the one furthest from the nominal). An image of the label is shown in Figure 10.

Figure 10 - Brazilian Label for Liquid-Filled Distribution Transformers

Canada

Scope of Coverage

Canada has mandatory regulations on dry-type transformers and voluntary efficiency levels on liquid-filled distribution transformers. The regulations on dry-type transformers apply to either single phase and nominal power of 15 to 833 kVA, or three-phase and nominal power of 15 to 7500 kVA, a frequency of 60 Hz and with a high voltage winding of 35 kV or less. The standard does not cover several special types of transformers, including the following: auto transformers; drive (isolation) transformers with two or more output windings or a nominal low-voltage line current greater than 1500 A; grounding transformers; rectifier transformers; sealed transformers; non-ventilated transformers, including encapsulated; testing transformers; furnace transformers; welding transformers; special impedance transformers; transformers with a nominal low-voltage line current of 4000 A or more; on-load regulating transformers, and resistance grounding transformers. Canada also has voluntary liquid-filled distribution transformer efficiency requirements that apply to single-phase and three-phase, 60 Hz, distribution transformers, rated between 10 and 833 kVA for single-phase and between 15 kVA and 3000 kVA for three-phase with a primary voltage of 34.5 kV or less.

Test Standard

The test standard is defined in CAN/CSA C802.2-06 - Minimum Efficiency Values for Dry-type Transformers, and refers to National Electrical Manufacturer's Association NEMA TP 2-2005 (NEMA, 2005), which is based on the IEEE test standards.

Energy Efficient Distribution Transformer Policies

In 2005, Canada adopted levels for single and three-phase dry-type transformers. The levels were then updated in 2010 to harmonize with the requirements on single and three-phase medium voltage dry-type transformers in the United States, which took effect in January 2010. The national standard CSA C802.2 establishes minimum efficiency values for dry-type distribution transformers.

Dry-type transformers in Canada must meet or exceed the efficiency levels given in Table 7 and Table 8.

Table 7 - Single Phase Dry-type Transformer MEPS in Canada

Single Phase kVA Rating	20 to 45 kV BIL *(% efficiency)**	>45 to 95 kV BIL *(% efficiency)*	>95 to 199 kV *(% efficiency)*
15	98.10	97.86	97.60
25	98.33	98.12	97.90
37.5	98.49	98.30	98.10
50	98.60	98.42	98.20
50	98.60	98.42	98.20
75	98.73	98.57	98.53
100	98.82	98.67	98.63
167	98.96	98.83	98.80
250	99.07	98.95	98.91
333	99.14	99.03	98.99
500	99.22	99.12	99.09
667	99.27	99.18	99.15
833	99.31	99.23	99.20

*Percentage efficiency at 50% nominal load. BIL means basic impulse insulation level.

Table 8 - Three-phase Dry-type Transformer MEPS in Canada

Three-phase kVA Rating	20 to 45 kV BIL *(% efficiency)**	>45 to 95 kV BIL *(% efficiency)*	>95 to 199 kV *(% efficiency)*
15	97.50	97.18	96.80
30	97.90	97.63	97.30
45	98.10	97.86	97.60
75	98.33	98.12	97.90
112.5	98.49	98.30	98.10
150	98.60	98.42	98.20
225	98.73	98.57	98.53
300	98.82	98.67	98.63
500	98.96	98.83	98.80
750	99.07	98.95	98.91
1,000	99.14	99.03	98.99
1,500	99.22	99.12	99.09
2,000	99.27	99.18	99.15
2,500	99.31	99.23	99.20
3,000	99.34	99.26	99.24
3,750	99.38	99.30	99.28
5,000	99.42	99.35	99.33
7,500	99.48	99.41	99.39

*Percentage efficiency at 50% nominal load. BIL means basic impulse insulation level.

In addition to the mandatory program for dry-type distribution transformers, Canada conducted a market and technology assessment on liquid-filled distribution transformers and determined that MEPS would not be needed to ensure energy-efficient transformers were installed in the market. The Canadian electric utilities were already evaluating losses and purchasing highly efficient models, and therefore in place of a mandatory standard, the Canadian Standards Association (CSA) harmonized the Canadian standard with the NEMA voluntary standards based on NEMA TP 1. A voluntary agreement between National Resources Canada (NRCan) and the Canadian Electricity Association (CEA) to adopt the minimum efficiency level based on the CSA C802.1-00 standard is being used for liquid-filled transformers. More information about Canada standards and labeling program is available at: http://www.nrcan.gc.ca.

Even though the above standard is voluntary, a recent market analysis found that the nine provincial electric utilities had already incorporated energy efficiency into their transformer procurement practices. As a result of these practices, more than 95 percent of the liquid-filled distribution transformers sold in Canada already met the NEMA TP 1 efficiency levels (USDOE, 2013).

Canada is currently reviewing whether to adopt MEPS for liquid-filled distribution transformers, however no decision has been made at this time.

Table 9 gives the specifications of the voluntary agreement.

Table 9 - Voluntary Standard for Liquid-Type Distribution Transformers in Canada

kVA	Min. Low Voltage	Efficiency	kVA	Min. Low Voltage	Efficiency
10	120/240	98.20	15	208Y/120	97.89
15	120/240	98.41	30	208Y/120	98.20
25	120/240	98.63	45	208Y/120	98.41
50	120/240	98.84	75	208Y/120	98.63
75	120/240	98.94	150	208Y/120	98.84
100	120/240	98.94	225	208Y/120	98.94
167	120/240	99.05	300	208Y/120	98.94
250	120/240	99.15	500	208Y/120	99.05
333	120/240	99.01	750	208Y/120	99.15
333	277/480Y	99.15	1,000	208Y/120	99.06
500	277/480Y	99.26	1,000	480Y/277	99.15
667	277/480Y	99.37	1,500	480Y/277	99.26
833	277/480Y	99.37	2,000	480Y/277	99.37
			2,500	480Y/277	99.37
			3,000	480Y/277	99.37

Republic of Chile

Scope of Coverage

Since 2007, Chile has a voluntary labeling program defined in NCh3039, which covers single-phase distribution transformers from 10 kVA – 833 kVA and three-phase distribution transformers from 15 to 2,500 kVA, both dry- and liquid-filled distribution transformers with a primary voltage of 34.5 kV or less, and a secondary voltage of 600 V or less, rated for operations at a frequency of 50Hz.

Test Standard

The test standard for measuring the efficiency is defined by two norms, NCh2660 and NCh2661, which refer to NEMA TP 2-2005.

Energy Efficient Distribution Transformer Policies

In early 2005, the government of Chile established the National Program for Energy Efficiency (PPEE) under the Ministry of Economy to promote more efficient use of energy. In 2010, the PPEE has been replaced by the Chilean Energy Efficiency Agency (Agencia Chilena de Eficiencia Energética) to take over the implementation of energy efficiency policies and initiatives. The Chilean Energy Efficiency Agency is structured as an independent, nonprofit organization to support the competitiveness and sustainable development of Chile. More information on the Chilean Energy Efficiency Agency is available at: www.acee.cl.

The Chilean S&L program is implemented by the Ministry of Energy and focuses mainly on appliances used in the residential sector, except for distribution transformers and three-phase induction motors. More information on the S&L program is available at: http://www.energia.gob.cl/.

The voluntary labeling program for distribution transformers defined in NCh3039 was prepared by the PPEE but has never been made mandatory. Table 10 and Table 11 give the efficiency levels for Class 1 defined in the labeling program, which refers to NEMA TP-3.

Table 10 – Voluntary Energy-Efficiency Levels for Liquid-Type Distribution Transformers in Chile

Single-Phase Liquid-Filled		Three-Phase Liquid-Filled	
kVA	(% efficiency)	kVA	(% efficiency)
10	98.4	15	98.1
15	98.6	30	98.4
25	98.7	45	98.6
38	98.8	75	98.7
50	98.9	112.5	98.8
75	99.0	150	98.9
100	99.0	225	99.0
167	99.1	300	99.0
250	99.2	500	99.1
333	99.2	750	99.2
500	99.3	1,000	99.2
667	99.4	1,500	99.3
833	99.4	2,000	99.4
		2,500	99.4

Note: Efficiency is defined at 55°C and 50% load factor

Table 11 – Voluntary Energy-Efficiency Levels for Dry-Type Distribution Transformers in Chile

kVA Rating	Single Phase			kVA Rating	Three Phase		
	Low Voltage	Medium Voltage			Low Voltage	Medium Voltage	
		≤60 kV BIL	>60 kV BIL			≤60 kV BIL	>60 kV BIL
15	97.7	97.6	97.6	15	97.0	96.8	96.8
25	98.0	97.9	97.9	30	97.5	97.3	97.3
37.5	98.2	98.1	98.1	45	97.7	97.6	97.6
50	98.3	98.2	98.2	75	98.0	97.9	97.9
75	98.5	98.4	98.4	112.5	98.2	98.1	98.1
100	98.6	98.5	98.5	150	98.3	98.2	98.2
167	98.7	98.8	98.7	225	98.5	98.4	98.4
250	98.8	98.9	98.8	300	98.6	98.6	98.5
333	98.9	99.0	98.9	500	98.7	98.8	98.7
500	-	99.1	99.0	750	98.8	98.9	98.8
667	-	99.2	99.0	1,000	98.9	99.0	98.9
833	-	99.2	99.1	1,500	-	99.1	99.0
				2,000	-	99.2	99.0
				2,500	-	99.2	99.1

Note: Efficiency is defined at 75°C and 35% load factor for low voltage, 50% load factor for medium voltage

People's Republic of China

Scope of Coverage

China has mandatory energy efficiency standards for distribution transformers - both liquid-filled and dry-type. The national standards apply to liquid-filled distribution transformers of 30 kVA-1600 kVA and dry type of rated capacity of 30 kVA-2500 kVA.

Test Standard

Many Chinese national GB standards are adopted from ISO, IEC or other international standards developers, and distribution transformers are no exception. For distribution transformers, China covers and regulates both liquid-filled and dry-type. The test standard for measuring the efficiency of the transformer is the family of GB 1094 national standards, which are harmonized with IEC 60076.

Energy Efficient Distribution Transformer Policies

The national standard GB 20052-2013 establishes maximum allowable losses in three grades for three-phase distribution transformers. This standard is maintained by the China National Institute of Standardization (CNIS). It specifies the maximum allowable losses and sets test standards for liquid-filled and dry-type three-phase distribution transformers. The three grades of maximum losses are structured such that Grade 3 has the highest losses (i.e., least efficient) and Grade 1 has the lowest losses (i.e., most efficient) for silicon-core steel transformers. In addition, the standard has two separate product classes under Grade 1 and 2 for amorphous-core distribution transformers. More information about China's standards and labeling program is available at: http://www.cnis.gov.cn.

Table 12 summarizes the requirements contained in the National Chinese distribution transformer standard GB 20052-2013.

Table 12 - Summary of National Efficiency Standard for Three-phase Distribution Transformers in China

Type	Grade 3	Grade 2		Grade 1	
		Silicon	Amorphous	Silicon	Amorphous
Liquid-filled	S11	S13	S15	-No-load loss is equivalent to S13 -Loading loss is 20% lower than that of S13	-No-load loss is equivalent to S15 -Loading loss is 10% lower than S15
Dry-type	SC10	SC12	SCH 15	-No-load loss is 10% lower than SC 12 -Loading loss is 10% lower than SC12	-No-load loss is equivalent to SCH15 -Loading loss is 5% lower than SCH15

The standards have been regularly updated since 1999 with the Standard S7 and then S9. S9 has since been replaced by the current standard, S11 (Grade 3 above), which defines maximum levels for no-load and load losses. S11 will soon be replaced by S13, which will specify lower maximum loss levels (i.e., more energy-efficient).

The following tables present the Chinese requirements (in maximum losses) for liquid-filled and dry-type distribution transformers. The liquid-filled table provides one set of values for coil losses (i.e., load loss) measured at 100% of rated capacity and three different sets of values for core losses (i.e., no load loss).

Table 13 presents the standards for three-phase liquid-filled distribution transformers built with conventional silicon steel (cold-rolled, grain oriented - CRGO).

Table 13 - Maximum Core and Coil Losses for 3-Phase Liquid-Filled Transformers using Silicon Core Steel (CRGO) – China, GB 20052-2013

kVA	Grade 3, CRGO		Grade 2, CRGO		Grade 1, CRGO	
	Max No Load Loss (W)	Max Load Loss (W)	Max No Load Loss (W)	Max Load Loss (W)	Max No Load Loss (W)	Max Load Loss (W)
30	100	600	80	600	80	480
50	130	870	100	870	100	695
63	150	1,040	110	1,040	110	830
80	180	1,250	130	1,250	130	1,000
100	200	1,500	150	1,500	150	1,200
125	240	1,800	170	1,800	170	1,440
160	280	2,200	200	2,200	200	1,760
200	340	2,600	240	2,600	240	2,080
250	400	3,050	290	3,050	290	2,440
315	480	3,650	340	3,650	340	2,920
400	570	4,300	410	4,300	410	3,440
500	680	5,150	480	5,150	480	4,120
630	810	6,200	570	6,200	570	4,960
800	980	7,500	700	7,500	700	6,000
1,000	1,150	10,300	830	10,300	830	8,240
1,250	1,360	12,000	970	12,000	970	9,600
1,600	1,640	14,500	1,170	14,500	1,170	11,600

Table 14 presents the standards for three-phase liquid-filled distribution transformers built with amorphous material in the transformer core.

Table 14 -Maximum Losses for 3-Phase Liquid-Filled Distribution Transformers using Amorphous material - China, GB 20052-2013

kVA	Grade 2, Amorphous Core		Grade 1, Amorphous Core	
	Max No Load Loss (W)	Max Load Loss (W)	Max No Load Loss (W)	Max Load Loss (W)
30	33	600	33	540
50	43	870	43	785
63	50	1,040	50	935
80	60	1,250	60	1,125
100	75	1,500	75	1,350
125	85	1,800	85	1,620
160	100	2,200	100	1,980
200	120	2,600	120	2,340
250	140	3,050	140	2,745
315	170	3,650	170	3,285
400	200	4,300	200	3,870
500	240	5,150	240	4,635
630	320	6,200	320	5,580
800	380	7,500	380	6,750
1,000	450	10,300	450	9,270
1,250	530	12,000	530	10,800
1,600	630	14,500	630	13,050

Similarly, for dry-type three-phase distribution transformers, the Chinese standard has three different levels of maximum no-load (i.e., core) losses - Grade 3 to Grade 1, with the latter being the lowest or most efficient. However, the standard also maintains a classification of load (i.e., winding) losses that vary with the designed temperature rise of the windings. For example, class B windings are the most efficient with a 100°C temperature rise and class H are the least efficient with a 145°C temperature rise. For ease of presentation in this report, the temperature rise "F" losses are presented in the following tables, which represent a 120°C temperature rise.

Table 15 presents the standards for three-phase dry-type distribution transformers built with conventional silicon core steel (cold-rolled, grain oriented - CRGO), based on GB 20052-2013.

Table 15 -Maximum Losses for 3-Phase Dry-Type Transformers using Silicon Core Steel (CRGO) in China, GB 20052-2013

kVA	Grade 3, Class F (120°C)		Grade 2, Class F (120°C)		Grade 1, Class F (120°C)	
	Max No Load Loss (W)	Max Load Loss (W)	Max No Load Loss (W)	Max Load Loss (W)	Max No Load Loss (W)	Max Load Loss (W)
30	190	710	150	710	135	640
50	270	1,000	215	1,000	195	900
80	370	1,380	295	1,380	265	1,240
100	400	1,570	320	1,570	290	1,415
125	470	1,850	375	1,850	340	1,665
160	540	2,130	430	2,130	385	1,915
200	620	2,530	495	2,530	445	2,275
250	720	2,760	575	2,760	515	2,485
315	880	3,470	705	3,470	635	3,125
400	980	3,990	785	3,990	705	3,590
500	1,160	4,880	930	4,880	835	4,390
630	1,340	5,880	1,070	5,880	965	5,290
800	1,520	6,960	1,215	6,960	1,095	6,265
1,000	1,770	8,130	1,415	8,130	1,275	7,315
1,250	2,090	9,690	1,670	9,690	1,505	8,720
1,600	2,450	11,730	1,960	11,730	1,765	10,555
2,000	3,050	14,450	2,440	14,450	2,195	13,005
2,500	3,600	17,170	2,880	17,170	2,590	15,455

Table 16 presents the standards for three-phase dry-type distribution transformers built with amorphous material in the transformer core. These requirements are also based on GB 20052-2013.

Table 16 - Maximum Loss for 3-Phase Dry-Type Transformers using Amorphous Material in China, GB 20052-2013

kVA	Grade 2, Amorphous, F (120°C)		Grade 1, Amorphous, F (120°C)	
	No Load Loss (W)	Load Loss (W)	No Load Loss (W)	Load Loss (W)
30	70	710	70	675
50	90	1,000	90	950
80	120	1,380	120	1,310
100	130	1,570	130	1,490
125	150	1,850	150	1,760
160	170	2,130	170	2,025
200	200	2,530	200	2,405
250	230	2,760	230	2,620
315	280	3,470	280	3,295
400	310	3,990	310	3,790
500	360	4,880	360	4,635
630	420	5,880	420	5,585
800	480	6,960	480	6,610
1,000	550	8,130	550	7,725
1,250	650	9,690	650	9,205
1,600	760	11,730	760	11,145
2,000	1,000	14,450	1,000	13,725
2,500	1,200	17,170	1,200	16,310

China also has a professional standard (or an “industry standard”) that establishes maximum loss levels on single-phase liquid-filled distribution transformers: JB/10317-02 "Technical Parameter and Requirement of Single-phase Liquid-filled Distribution Transformer". Table 17 presents the maximum losses associated with these standards. These are not a national mandatory requirement, but should instead be interpreted as voluntary guidance / recommendations for industrial customers.

Table 17 - Maximum Losses for Single-Phase Liquid-Filled Distribution Transformers in China, JB/10317-02

kVA	Single-Phase Liquid-Filled Transformers	
	No Load Loss (W)	Load Loss (W)
5	35	145
10	55	260
16	65	365
20	80	430
30	100	625
40	125	775
50	150	950
63	180	1,135
80	200	1,400
100	240	1,650
125	285	1,950
160	365	2,365

Finally, China also has an endorsement label implemented by the China Certification Centre for Energy Conservation Product (CECP) (now managed by the Quality Certification Centre - CQC), which was established by the State Economic and Trade Commission (now the National Development and Reform Commission - NDRC) and the China State Bureau of Quality and Technical Supervision (now the General Administration of Quality Supervision, Inspection and Quarantine - AQSIQ). One of the first priorities was to establish the label for refrigerators. The labeling of compact fluorescent lamps quickly followed with the assistance of the Greenlights program. Since this time, many more appliances and equipment types have been added to the program. Three-phase distribution transformers have been added to the list of products covered in 2013. The label application is similar to the US Energy Star Label, but does also require a factory check and is subject to a mandatory quality program. Products applying for the certification mark are required to undertake a third party certification process to be able to use the label. An image of China’s endorsement label is given below.

Figure 11 - China’s Endorsement Label

Republic of Colombia

Scope of Coverage

Colombia has voluntary energy efficiency standards for single-phase liquid-filled distribution transformers with rated capacity between 5 and 167.5 kVA and three-phase liquid-filled distribution transformers with rated capacity between 15 kVA and 10,000 kVA.

Test Standard

The Colombian test standard for distribution transformers is defined in Norma Técnica Colombiana NTC 380, which references the IEC test method, IEC 60076-1.

Energy Efficient Distribution Transformer Policies

The Instituto Colombiano de Normas Técnicas y Certificación, ICONTEC, defines the maximum losses of liquid-filled single phase and three-phase distribution transformers through a set of NTC standards covering different aspects of the distribution transformer standard - such as definitions, (NTC 3997, NTC 317, NTC 4406, NTC 818, NTC 819). The following table summarizes the maximum losses defined in NTC 818 (single phase) and NTC 819 (three phase). The regulation also defines allowable current at no load (i.e., open circuit) and under short circuit conditions that are not presented in this report. More information about Colombia's standards and labeling program is available at: http://icontec.org/index.php.

Table 18 - Maximum Losses for Single-Phase Liquid-Filled Distribution Transformers in Colombia (Voluntary Standards)

kVA	≤ 15kV Primary / ≤ 1.2kV Secondary		≤ 34.5kV Primary / ≤ 1.2kV Secondary	
	Max No Load Loss (W)	Max Load Loss (W)	Max No Load Loss (W)	Max Load Loss (W)
5	30	90	-	-
10	50	140	-	-
15	70	195	-	-
25	100	290	185	360
37.5	135	405	230	490
50	160	510	265	605
75	210	710	330	820
100	260	900	385	1,020
167.5	375	1365	510	1,500

Table 19 - Maximum Losses for Three-Phase Liquid-Filled Distribution Transformers in Colombia (Voluntary Standard)

kVA	<15kV Primary / ≤ 1.2kV Secondary		≤ 46kV Primary / ≤ 1.2kV Secondary	
	Max No Load Loss (W)	Max Load Loss (W)	Max No Load Loss (W)	Max Load Loss (W)
15	80	310		
30	135	515		
45	180	710		
75	265	1,090	390	1,370
112.5	365	1,540	500	1,890
150	450	1,960	610	2,400
225	615	2,890	790	3,330
300	765	3,575	950	4,210
400	930	4,730	1,150	5,320
500	1,090	5,780	1,330	6,370
630	1,285	7,140	1,540	7,690
750	1,450	8,380	1,730	8,860
800	1,520	8,900	1,800	9,330
1,000	1,780	11,100	1,980	12,000
1,250	2,090	13,500	2,370	14,300
1,600	2,520	16,700	2,880	17,400
2,000	3,010	20,400	3,430	20,900
2,500	3,620	25,000	4,100	25,000
3,000	4,230	29,700	4,740	29,000
3,750	5,160	36,600	5,650	34,400
4,000			5,950	36,100
5,000			7,100	42,600
6,000			8,200	48,200
7,500			9,790	55,100
10,000			12,300	61,000

European Union

Scope of Coverage

In May 2014, the European Commission published an implementing measure for 'small, medium, and large power transformers' under the Ecodesign Directive which established MEPS for this equipment in Europe (EC, 2014). This regulation covers transformers used in 50 Hz electricity transmission and distribution networks and in commercial and industrial installations, with a minimum rating of 1 kVA. The regulations establish maximum load and no-load losses for three-phase liquid-filled and dry-type transformers. It includes both liquid-filled and dry-type transformers, but excludes the following categories of transformers: (1) instrument transformers; (2) traction transformers on rolling stock; (3) starting transformers; (4) testing transformers; (5) welding transformers; (6) explosion-proof and underground mining transformers; and (7) transformers for deep water (submerged) applications.

As yet, there are no requirements on single-phase transformers in Europe, although the regulation specifically instructs the Commission to review whether single-phase requirements would be justified in a review of the regulation due in June 2017.[3] In addition, there are no labeling requirements for distribution transformers, as the Commission determined that applying the A to G label would not have a significant impact on the market due to the way transformers are specified and purchased.

Test Standard

The European Norms EN50464-1 and EN50564-1 both reference the international IEC 60076 family of standards for the measurement of losses associated with a transformer.

Energy Efficient Distribution Transformer Policies

Table 20 and Table 21 set out the MEPS for three-phase, liquid-filled and dry-type, medium power transformers in Europe (EC, 2014). The first set of requirements took effect on 1 July 2015 and the second (more stringent) tier will take effect on 1 July 2021. More information about the European Union's standards and labeling program is available at: https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficient-products.

[3] The regulation states that by June 2017, the Commission must have reviewed several aspects, including: "the appropriateness of establishing minimum performance requirements for single-phase power transformers, as well as for small power transformers".

Table 20 - Maximum load and no-load losses for three-phase liquid-filled distribution transformers, 24kV primary voltage, European Union (EU No 548/2014)

24 kV	Tier 1 (from 1 July 2015)		Tier 2 (from 1 July 2021)	
kVA	Maximum no-load losses (W)	Maximum load losses (W)	Maximum no-load losses (W)	Maximum load losses (W)
≤25	70	900	63	600
50	90	1,100	81	750
100	145	1,750	130	1,250
160	210	2,350	189	1,750
250	300	3,250	270	2,350
315	360	3,900	324	2,800
400	430	4,600	387	3,250
500	510	5,500	459	3,900
630	600	6,500	540	4,600
630	650	8,400	585	6,000
800	770	10,500	693	7,600
1,000	950	11,000	855	9,500
1,250	1,200	14,000	1,080	12,000
1,600	1,450	18,000	1,305	15,000
2,000	1,750	22,000	1,575	18,500
2,500	2,200	27,500	1,980	23,000

Table 21 - Maximum load and no-load losses for three-phase dry-type distribution transformers, 24kV primary voltage, European Union (EU No 548/2014)

24 kV	Tier 1 (from 1 July 2015)		Tier 2 (from 1 July 2021)	
kVA	Maximum no-load losses (W)	Maximum load losses (W)	Maximum no-load losses (W)	Maximum load losses (W)
50	200	1,700	180	1,500
100	280	2,050	252	1,800
160	400	2,900	360	2,600
250	520	3,800	468	3,400
400	750	5,500	675	4,500
630	1,100	7,600	990	7,100
800	1,300	8,000	1,170	8,000
1,000	1,550	9,000	1,395	9,000
1,250	1,800	11,000	1,620	11,000
1,600	2,200	13,000	1,980	13,000
2,000	2,600	16,000	2,340	16,000
2,500	3,100	19,000	2,790	19,000
3,150	3,800	22,000	3,420	22,000

The levels of load and no load losses indicated in Table 20 and Table 21 are not applicable to liquid immersed pole-mounted transformers with power ratings between 25 kVA and 315 kVA. These requirements for pole-mounted transformers are less stringent than those for pole-mounted transformers in other economies around the world. However, the Commission is required to review that concession made for pole-mounted transformers as part of the review due in June 2017. For these specific models of medium power pole-mounted transformers, the maximum levels of allowable losses are set out in Table 22.

Table 22 - Maximum load and no-load losses for medium power liquid immersed pole-mounted transformers (EU No 548/2014)

	Tier 1 (from 1 July 2015)		Tier 2 (from 1 July 2021)	
kVA	Maximum no-load losses (W)	Maximum load losses (W)	Maximum no-load losses (W)	Maximum load losses (W)
25	70	900	70	725
50	90	1,100	90	875
100	145	1,750	145	1,475
160	300	3,102	270	3,102
200	356	2,750	310	2,333
250	425	3,250	360	2,750
315	520	3,900	440	3,250

In addition to distribution transformers, the recent European regulation establishes requirements for transformers with rated power >3150 kVA expressed as minimum Peak Efficiency Index (PEI) values for liquid-filled and dry-type transformers.

Republic of India

Scope of Coverage

On 5 January 2010, India adopted a mandatory labeling scheme for specific types of liquid-filled, naturally air-cooled, three-phase distribution transformers. These are the units referred to under Indian Standard IS 1180 (part I) and cover power ratings up to and including 200 kVA. More specifically, the standard ratings covered under the energy labeling scheme are 16, 25, 63, 100, 160, and 200 kVA.

This scope of coverage in India is currently under review by the Bureau of Indian Standards (BIS) and the Bureau of Energy Efficiency (BEE). In 2014, BIS updated the Indian Standard (IS) 1180 (part 1): 1989 "Outdoor type oil immersed distribution transformers up to and including 2500 kVA, 33kV [*Fourth Revision of* IS 1180 (Part 1)]". In this document, the revision of the national distribution transformer standard (BIS standard) extends the scope of coverage beyond 200 kVA and up to and including 2500 kVA and 33 kilovolts. This extension of the scope would bring India's coverage more in line with other major economies such as Australia, China, and the US. Following the publication of the revised version of the IS 1180 Part I standard, BEE is also in the process of revising their labeling standard.

Test Standard

The testing code and procedure for the distribution transformers is found in IS 1180 (part 1): 1989 with all amendments to date (as described above) and IS 1180 (Part 2): 1989 "Outdoor Type Three-Phase Distribution Transformers up to and including 100 kVA 11 kV, sealed type".

Both parts of the Indian Standard cross-reference a series of other Indian Standards, which are based on the international family of standards, IEC 60076.

Energy Efficient Distribution Transformer Policies

Figure 12 shows the mandatory labeling scheme for distribution transformers in India. The star system constitutes a useful tool for differentiating between models at the same rating. More information about the India standards and labeling program is available at: https://beenet.gov.in.

It is also important to note that in a notification dated 20 August 2010, the Central Electricity Authority (CEA) of India issued a requirement that all utilities in India must procure at least a 3 star distribution transformer.[4] Since that time, transformer purchase orders issued by the utilities prescribe a minimum of 3 star distribution transformers.

[4] Installation of energy-efficient 3-Star rated distribution transformers is required by the Indian Government. Notification was issued by the Government of India vide No:2/11/(5)/03-BEE-3, Dtd: 05.03.2010 and the Central Electricity Authority Notification No: CEA/TETD/MP/R/01/2010 dt: 20.08.2010 under section 177 of Electricity Act 2003 on the procurement of Star Rated Energy Efficient Distribution Transformer.

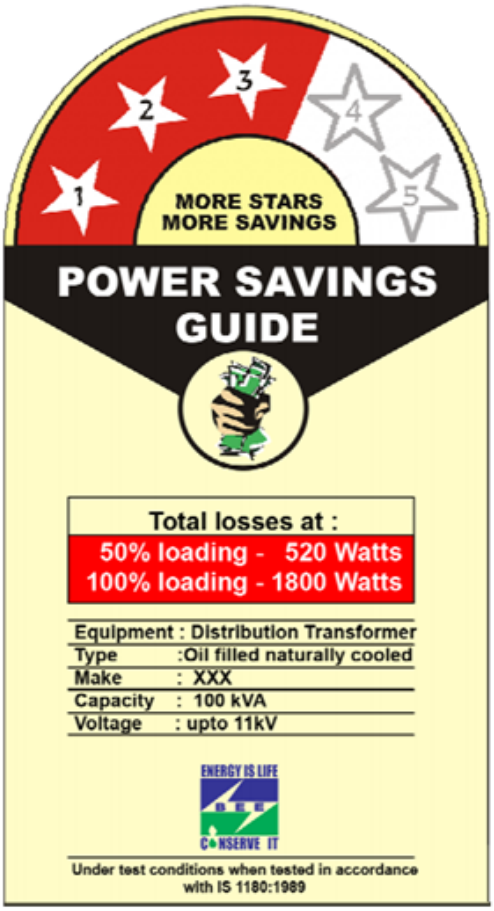

Figure 12 - India's Energy Efficiency Label for Liquid-Immersed Distribution Transformers

The highest loss designs (i.e., the least efficient) are defined as one star and lowest loss segment (i.e., the most efficient) are defined as a five star. The basis for the star rating is given in the table below.

Table 23 - Definition of India's Five Star Energy-Efficiency Label for Transformers

Case	Basis of Losses (Total at 50% Load Condition)
1 Star	Current purchasing practice (IS 1180 (part 1)Max Losses)
2 Star	Some utility purchase specifications like AP, NDPL
3 Star	Losses from Total Ownership Cost (TOC) design (Moderate)
4 Star	Losses from lowest TOC design
5 Star	High efficiency design

Table 24 presents the corresponding maximum total losses associated with each of the five star levels, measured at 50% and 100% of loading. These are total losses - in that they are the sum of the core and coil losses together. These maximum total loss levels are for liquid-filled distribution transformers, typical of those used by an electric utility in a distribution network.

Table 24 - Maximum Losses for Liquid-Filled Distribution Transformers in India

Rating	1 Star		2 Star		3 Star*		4 Star		5 Star	
kVA	Losses 50% (W)	Losses 100% (W)	Losses 50% (W)	Losses 100% (W)	Losses 50% (W)	Losses 100% (W)	Losses 50% (W)	Losses 100% (W)	Losses 50% (W)	Losses 100% (W)
16	200	555	165	520	150	480	135	440	120	400
25	290	785	235	740	210	695	190	635	175	595
63	490	1,415	430	1,335	380	1,250	340	1,140	300	1,050
100	700	2,020	610	1,910	520	1,800	475	1,650	435	1,500
160	1,000	2,800	880	2,550	770	2,200	670	1,950	570	1,700
200	1,130	3,300	1,010	3,000	890	2,700	780	2,300	670	2,100

* Note: Minimum procurement specification from the Indian Central Electricity Authority, as per a notification issued on 20 August 2010.

State of Israel

Scope of Coverage

Israel has adopted national minimum efficiency regulations for distribution transformers, covering both efficiency requirements and labeling. The Israeli Standards Institute (ISI) issued Israeli Standard 5484, Distribution transformers - energy efficiency requirements and marking, which applies to distribution transformers with nominal input voltage of 22kV or 33kV and a nominal output voltage of 400V, with power ratings up to 2500 kVA are designed to operate in Israel's 50Hz distribution system. Israeli Standard 5484 is voluntary and is currently under revision.

Test Standard

The Israeli standards are based on the family of international standards published by the IEC, 60076.

Energy Efficient Distribution Transformer Policies

There are six tables of maximum core and coil losses that are given in the Israeli regulation. The regulation contains tables that are applicable to liquid-filled distribution transformers and tables that apply to dry-type (cast resin coil). The national standard does not apply to special purpose transformers such as metering transformers, testing transformers, welding transformers, starter transformers, and other special-purpose transformers.

Table 25, Table 26, and Table 27 present the efficiency requirements for Israel, with maximum coil losses measured at 100% of rated capacity. Like the Australians, Israel has published both a minimum efficiency level (MEPS) and they have published a high efficiency performance standard (HEPS) - both of which are based on defining levels of maximum losses. More information about Israel standards and labeling program is available at: http://energy.gov.il/english/Pages/default.aspx.

Table 25 - Maximum Losses for Liquid-Filled Distribution Transformers in Israel, Voluntary Standard

kVA	≤ 22kV Primary Voltage		≤ 33kV Primary Voltage	
	Max Core Losses (W)	Max Coil Losses (W)	Max Core Losses (W)	Max Coil Losses (W)
100	230	1,760	240	1,700
160	300	2,330	300	2,470
250	450	3,330	450	3,410
400	650	4,670	650	4,830
630	900	5,460	950	5,780
800	1,180	8,320	1,450	7,950
1,000	1,300	9,700	1,560	9,450
1,250	1,500	11,300	1,810	10,950
1,600	1,800	14,500	2,160	14,250
2,000	2,150	16,150	2,580	16,320
2,500	2,540	19,100	2,950	19,850

Table 26 - Maximum Losses for Liquid-Filled Distribution Transformers in Israel, High Efficiency Performance Standard

kVA	≤ 22kV Primary		≤ 33kV Primary	
	Max Core Losses (W)	Max Coil Losses (W)	Max Core Losses (W)	Max Coil Losses (W)
100	190	1,670	230	1,410
160	260	2,170	330	2,075
250	380	2,250	410	2,960
400	550	3,020	590	4,120
630	690	4,520	870	4,520
800	790	6,820	1,040	6,470
1,000	930	7,650	1,250	7,520
1,250	1,100	9,550	1,520	9,570
1,600	1,320	11,850	1,870	11,840
2,000	1,700	14,240	2,210	14,900
2,500	2,000	17,520	2,650	17,800

Table 27 - Maximum Losses for Dry-Type (Cast-Resin) Transformers in Israel, Voluntary Standard and Efficient

kVA	≥ 22kV Primary Minimum Efficiency		≥ 22kV Primary High Energy Efficiency	
	Max Core Losses (W)	Max Coil Losses (W)	Max Core Losses (W)	Max Coil Losses (W)
100	550	1,700	300	1,700
160	750	2,300	390	2,300
250	1,020	3,300	550	3,000
400	1,380	4,800	870	4,700
630	1,900	6,930	1,100	6,300
800	2,250	7,800	1,400	7,500
1000	2,650	9,100	1,550	8,700
1250	3,050	11,000	2,000	10,600
1600	3,600	13,500	2,250	13,000
2000	4,620	14,500	2,950	12,500
2500	5,750	17,000	3,400	14,000

Japan

Scope of Coverage

In Japan, distribution transformer efficiency is covered by the national "Top Runner" efficiency program for electrical appliances and equipment. Under the Top Runner program, the listed efficiency levels are not mandatory but are set at very high levels with the aim being to provide a targeted level that can be used to encourage manufacturers to strive to continually improve efficiency. The Top Runner program covers single-phase and three-phase liquid-filled and dry-type distribution transformers from 5kVA to 2000kVA.

Test Standard

The Japanese Industrial Standards JIS C4304 - 2005 are used to measure the losses of 6kV liquid-filled distribution transformers and the standard JIS C4306 - 2005 is used to measure 6kV cast-coil dry-type distribution transformers. These test standards are based on the IEC 60076 family of standards, however minor modifications have been made when adopting the IEC standards to the Japanese national standards.

Energy Efficient Distribution Transformer Policies

Distribution transformers are included in the Top Runner program which specifies target levels of total losses for use in determining transformer efficiency (METI, 2010). Rather than separating the no load and load loss, the program provides empirical formulas that can be used to calculate the losses for any specific transformer rating. The loss formulas are given for both 50 and 60 Hz to cover the two different power frequency systems that operate in separate parts of Japan.

Table 28 - Japanese Top Runner Program Requirements

Category				Energy Consumption Efficiency*
Type	Number of Phases	Rated Frequency	Rated Capacity	
Liquid-filled transformer	Single Phase	50 Hz		$E = 15.3 \times S^{0.696}$
		60 Hz		$E = 14.4 \times S^{0.698}$
	Three Phase	50 Hz	Up to 500 kVA	$E = 23.8 \times S^{0.653}$
			Over 500 kVA	$E = 9.84 \times S^{0.842}$
		60 Hz	Up to 500 kVA	$E = 22.6 \times S^{0.651}$
			Over 500 kVA	$E = 18.6 \times S^{0.745}$
Cast-coil Dry-type transformers	Single Phase	50 Hz		$E = 22.9 \times S^{0.647}$
		60 Hz		$E = 23.4 \times S^{0.643}$
	Three Phase	50 Hz	Up to 500 kVA	$E = 33.6 \times S^{0.626}$
			Over 500 kVA	$E = 24.0 \times S^{0.727}$
		60 Hz	Up to 500 kVA	$E = 32.0 \times S^{0.641}$
			Over 500 kVA	$E = 26.1 \times S^{0.716}$

*In the formula, E is standard energy consumption efficiency (unit: Watt) and S is the rated capacity (unit: kVA).

In addition to the Top Runner program, Japan also promotes the use of energy-efficient equipment through a voluntary Energy Saving Labeling Program. This program is administered by the Energy Conservation Centre, Japan (ECCJ). The voluntary labeling program was launched in 2000, and it allows consumers to compare energy efficiencies of similar products when making a purchase. As of August 2004, there were 13 target products covered as part of the program including air conditioners, fluorescent lights, TVs, refrigerators, freezers, space heaters, gas cooking appliances, gas burning heaters, liquid burning water heaters, electric toilet seats, computers, magnetic disk units, and distribution transformers. More information about Japan standards and labeling program is available at: http://www.asiaeec-col.eccj.or.jp/index.html.

Figure 13 shows the two types of labels used in the Energy Saving Labeling Program - one to indicate the target has not been achieved and one to indicate it has been achieved. The label presents the target fiscal year, the achievement rate in terms of the energy conservation standards and the annual energy consumption in kWh/year. The symbol changes from an orange "e" to a green "e" once the target has been achieved - i.e., the 'achievement rate of energy conservation standards' has surpassed 100% of the target value.

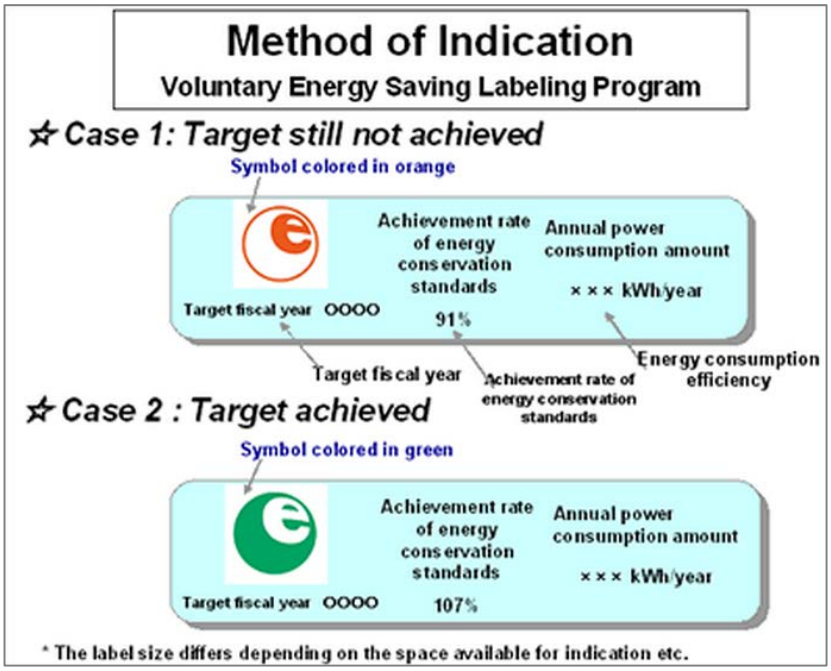

Figure 13 - Energy Saving Labeling Program in Japan

Republic of Korea

Scope of Coverage

The MEPS program for liquid-filled and dry-type distribution transformers in Korea was recently updated in 2015 to increase the energy-efficiency requirements for single-phase distribution transformers between 10 and 3000kVA and three-phase transformers between 100 and 3000kVA.

Test Standard

The national Korean Standards (KS) used for the testing of distribution transformers in Korea, KS C 4306, KS C 4311, KS C 4316, KS C 4317, all cross-reference the measurement methodologies that are published in the IEC 60076 standards. These standards were adopted without modification (i.e., "identical") as national Korean Standards (KS). KS C IEC 60076-1, Power transformers - Part 1: General, corresponds to IEC 60076-1:1993 and is identical to that standard.

Energy Efficient Distribution Transformer Policies

The energy efficiency regulation sets a MEPS and Target Energy Performance Standard (TEPS) at 50% load factor for three different type of primary voltage/secondary voltage combination as shown in Table 29 through Table 35. More information about Korea standards and labeling program is available at: http://www.kemco.or.kr/web/kem_home_new/new_main.asp.

Table 29 - Korean MEPS and TEPS for Single Bushing Transformers with Primary voltage/Secondary voltage 13.2 kV/230 V

Capacity (kVA)	From 1st of July, 2012		From 1st of October, 2016	
	Single Phase MEPS (% efficiency)	Single Phase TEPS (% efficiency)	Single Phase MEPS (% efficiency)	Single Phase TEPS (% efficiency)
10	98.3	98.7	98.70	98.75
20	98.5	98.8	98.80	98.95
30	98.7	98.9	98.90	99.05
50	98.8	99.0	99.00	99.15
75	98.8	99.1	99.10	99.20
100	98.9	99.2	99.10	99.25

Note: Testing according to KS C4306.

Table 30 - Korean MEPS and TEPS for 3.3-6.6kV Primary/Low Voltage Secondary Dry-Type Distribution Transformers

Number of phases	Capacity (kVA)	From 1st of July, 2012		From 1st of October, 2015	
		MEPS	TEPS	MEPS	TEPS
Single phase	50	97.7	98.7	97.90	98.70
	75	97.8	98.8	98.00	98.80
	100	98.0	98.9	98.10	98.90
	150	98.2	99.0	98.30	99.00
	200	98.4	99.0	98.50	99.05
	300	98.5	99.1	98.60	99.15
	400	98.6	99.2	98.70	99.20
	500	98.7	99.3	98.80	99.30
	600	98.7	99.3	98.80	99.30
	750	98.8	99.3	98.90	99.30
	1000	99.0	99.4	99.00	99.40
	1250	99.1	99.5	99.10	99.50
	1500	99.1	99.5	99.10	99.50
	2000	99.2	99.5	99.20	99.50
	2500	99.3	99.5	99.30	99.50
	3000	99.4	99.5	99.40	99.50
3-phase	50	97.7	98.7	97.90	98.70
	75	97.8	98.8	98.00	98.80
	100	98.0	98.9	98.10	98.90
	150	98.2	99.0	98.30	99.00
	200	98.4	99.0	98.50	99.00
	300	98.5	99.1	98.60	99.10
	400	98.6	99.2	98.70	99.20
	500	98.7	99.3	98.80	99.30
	600	98.7	99.3	98.80	99.30
	750	98.8	99.3	98.90	99.30
	1,000	98.9	99.4	99.00	99.40
	1,250	99.0	99.5	99.10	99.50
	1,500	99.0	99.5	99.10	99.50
	2,000	99.1	99.5	99.20	99.50
	2,500	99.2	99.5	99.20	99.50
	3,000	99.3	99.5	99.30	99.50

Note: Testing according to KS C4311. New MEPS&TEPS for transformers with capacity less than 1500 kVA will go effective Oct 1, 2016

Table 31 - Korean MEPS and TEPS for 22.9kV Primary/Low Voltage Secondary Dry-Type Distribution Transformers

Number of phase	Capacity (kVA)	From 1st of July, 2012		From 1st of October, 2015	
		MEPS	TEPS	MEPS	TEPS
Single	50	97.6	98.7	97.80	98.70
	75	97.7	98.8	97.90	98.80
	100	97.9	98.8	98.00	98.90
	150	98.1	98.9	98.10	99.00
	200	98.3	99.0	98.30	99.05
	300	98.4	99.1	98.50	99.15
	400	98.5	99.2	98.60	99.25
	500	98.7	99.2	98.80	99.25
	600	98.7	99.3	98.80	99.30
	750	98.8	99.3	98.90	99.30
	1,000	98.9	99.4	99.00	99.40
	1,250	99.0	99.4	99.00	99.40
	1,500	99.0	99.5	99.10	99.50
	2,000	99.1	99.5	99.10	99.50
	2,500	99.2	99.5	99.20	99.50
	3,000	99.3	99.5	99.30	99.50
3-phase	50	97.6	98.7	97.80	98.70
	75	97.7	98.8	97.90	98.90
	100	97.8	98.8	98.00	99.00
	150	98.0	98.9	98.10	99.00
	200	98.2	99.0	98.30	99.10
	300	98.4	99.1	98.50	99.20
	400	98.5	99.2	98.60	99.20
	500	98.7	99.2	98.80	99.30
	600	98.7	99.3	98.80	99.30
	750	98.8	99.3	98.90	99.40
	1,000	98.9	99.4	99.00	99.40
	1,250	98.9	99.4	99.00	99.50
	1,500	99.0	99.5	99.10	99.50
	2,000	99.1	99.5	99.10	99.50
	2,500	99.2	99.5	99.20	99.50
	3,000	99.2	99.5	99.20	99.50

Note: Testing according to KS C4311. New MEPS&TEPS for transformers with capacity less than 1500 kVA will go effective Oct 1, 2016

Table 32 - Korean MEPS and TEPS for 22.9kV Primary / 3.3-6.6 kV Secondary Dry-Type Distribution Transformers

Number of phase	Capacity (kVA)	From 1st of July, 2012		From 1st of October, 2015	
		MEPS	TEPS	MEPS	TEPS
Single	50	97.6	98.7	97.80	98.70
	75	97.7	98.8	97.90	98.80
	100	97.8	98.8	98.00	98.80
	150	98.0	98.9	98.10	98.90
	200	98.2	99.0	98.30	99.00
	300	98.4	99.0	98.50	99.00
	400	98.5	99.1	98.60	99.20
	500	98.7	99.2	98.80	99.20
	600	98.7	99.3	98.80	99.30
	750	98.8	99.3	98.90	99.40
	1,000	98.9	99.4	99.00	99.40
	1,250	98.9	99.4	99.00	99.50
	1,500	99.0	99.5	99.10	99.50
	2,000	99.1	99.5	99.20	99.50
	2,500	99.2	99.5	99.30	99.50
	3,000	99.2	99.5	99.30	99.50
3-phase	50	97.6	98.7	97.80	98.70
	75	97.7	98.8	97.80	98.80
	100	97.8	98.8	97.90	98.90
	150	98.0	98.9	98.10	99.00
	200	98.2	99.0	98.30	99.05
	300	98.4	99.0	98.50	99.10
	400	98.5	99.1	98.60	99.20
	500	98.7	99.2	98.70	99.25
	600	98.7	99.3	98.80	99.30
	750	98.8	99.3	98.80	99.30
	1,000	98.9	99.4	98.90	99.40
	1,250	98.9	99.4	98.90	99.40
	1,500	99.0	99.5	99.00	99.50
	2,000	99.1	99.5	99.20	99.50
	2,500	99.2	99.5	99.30	99.50
	3,000	99.2	99.5	99.30	99.50

Note: Testing according to KS C4311. New MEPS&TEPS for transformers with capacity less than 1500 kVA will go effective Oct 1, 2016

Table 33 - Korean MEPS and TEPS for Low Voltage Liquid-Filled Distribution Transformers

Number of phase	Capacity (kVA)	From 1st of July, 2012		From 1st of October, 2015	
		MEPS	TEPS	MEPS	TEPS
Single	100	98.4	99.0	98.70	99.20
	150	98.4	99.0	98.70	99.20
	200	98.4	99.0	98.70	99.25
	250	98.5	99.1	98.80	99.30
	300	98.5	99.1	98.80	99.35
	400	98.6	99.2	98.90	99.35
	500	98.6	99.2	98.90	99.40
	600	98.6	99.2	98.90	99.40
	750	98.7	99.3	99.00	99.45
	1,000	98.8	99.3	99.00	99.50
	1,250	98.8	99.4	99.10	99.50
	1,500	98.9	99.4	99.10	99.50
	2,000	99.0	99.4	99.20	99.50
	2,500	99.0	99.4	99.20	99.50
	3,000	99.1	99.4	99.20	99.50
3-phase	100	98.0	99.0	98.50	99.00
	150	98.1	99.0	98.50	99.05
	200	98.2	99.0	98.60	99.10
	250	98.3	99.1	98.70	99.15
	300	98.4	99.1	98.70	99.20
	400	98.4	99.2	98.80	99.25
	500	98.5	99.2	98.80	99.25
	600	98.5	99.2	98.80	99.30
	750	98.6	99.3	98.90	99.30
	1,000	98.7	99.3	99.00	99.35
	1,250	98.8	99.4	99.10	99.40
	1,500	98.8	99.4	99.10	99.45
	2,000	98.9	99.4	99.10	99.45
	2,500	99.0	99.4	99.20	99.50
	3,000	99.1	99.4	99.20	99.50

Notes: Testing according to KS C4316, KS C4317. New MEPS&TEPS for transformers with capacity less than 1500 kVA will go effective Oct 1, 2016.

Table 34 - Korean MEPS and TEPS for 22.9 kV/Low voltage Liquid-Filled Distribution Transformers

Number of phase	Capacity (kVA)	From 1st of July, 2012		From 1st of October, 2015	
		MEPS	TEPS	MEPS	TEPS
Single	10	97.4	98.6	98.00	98.65
	15	97.7	98.6	98.20	98.75
	20	97.9	98.7	98.30	98.75
	30	98.1	98.8	98.40	98.95
	50	98.4	98.8	98.60	99.05
	75	98.6	98.9	98.70	99.10
	100	98.7	99.0	98.80	99.15
	150	98.4	99.0	98.70	99.20
	200	98.4	99.0	98.70	99.30
	250	98.5	99.1	98.70	99.30
	300	98.5	99.1	98.80	99.35
	400	98.6	99.2	98.90	99.40
	500	98.6	99.2	98.90	99.45
	600	98.6	99.2	98.90	99.45
	750	98.7	99.3	99.00	99.50
	1,000	98.8	99.3	99.00	99.50
	1,250	98.8	99.4	99.10	99.50
	1,500	98.9	99.4	99.10	99.50
	2,000	99.0	99.4	99.20	99.50
	2,500	99.1	99.4	99.20	99.50
	3,000	99.2	99.4	99.30	99.50
3-phase	100	98.0	99.0	98.50	99.00
	150	98.1	99.0	98.50	99.05
	200	98.2	99.0	98.60	99.10
	250	98.3	99.1	98.70	99.20
	300	98.4	99.1	98.70	99.20
	400	98.4	99.1	98.70	99.25
	500	98.5	99.1	98.80	99.25
	600	98.5	99.2	98.80	99.30
	750	98.6	99.2	98.90	99.30
	1,000	98.7	99.3	99.00	99.35
	1,250	98.8	99.3	99.00	99.40
	1,500	98.8	99.3	99.00	99.45
	2,000	98.9	99.3	99.10	99.45
	2,500	99.0	99.4	99.20	99.50
	3,000	99.1	99.4	99.20	99.50

Note: Testing according to KS C4316, KS C4317. New MEPS&TEPS for transformers with capacity less than 1500 kVA will go effective Oct 1, 2016.

Table 35 - Korean MEPS and TEPS for 22.9kV/3.3-6.6 kV Liquid-Filled Distribution Transformers

Number of phase	Capacity (kVA)	From 1st of July, 2012		From 1st of October, 2015	
		MEPS	TEPS	MEPS	TEPS
Single	100	98.4	99.0	98.70	99.15
	150	98.5	99.0	98.70	99.20
	200	98.5	99.0	98.70	99.30
	250	98.6	99.1	98.80	99.30
	300	98.6	99.1	98.80	99.30
	400	98.7	99.2	98.90	99.35
	500	98.8	99.2	99.00	99.40
	600	98.8	99.2	99.00	99.45
	750	98.9	99.3	99.10	99.50
	1,000	98.9	99.3	99.10	99.50
	1,250	99.0	99.4	99.20	99.50
	1,500	99.0	99.4	99.20	99.50
	2,000	99.1	99.4	99.20	99.50
	2,500	99.1	99.4	99.20	99.50
	3,000	99.2	99.4	99.20	99.50
3-phase	100	98.1	99.0	98.50	99.00
	150	98.2	99.0	98.60	99.05
	200	98.2	99.0	98.60	99.10
	250	98.3	99.1	98.70	99.20
	300	98.4	99.1	98.70	99.20
	400	98.5	99.2	98.80	99.25
	500	98.6	99.2	98.90	99.25
	600	98.6	99.2	98.90	99.25
	750	98.6	99.3	98.90	99.30
	1,000	98.7	99.3	99.00	99.35
	1,250	98.8	99.4	99.10	99.40
	1,500	98.9	99.4	99.10	99.45
	2,000	99.0	99.4	99.20	99.45
	2,500	99.1	99.4	99.20	99.50
	3,000	99.2	99.4	99.30	99.50

Note: Testing according to KS C4316, KS C4317. . New MEPS&TEPS for transformers with capacity less than 1500 kVA will go effective Oct 1, 2016.

United Mexican States

Scope of Coverage

The scope of coverage for liquid-filled distribution transformers in Mexico includes single-phase and three-phase units, from 5 to 167 kVA capacity for single-phase and from 15 to 500 kVA capacity for three-phase. Covered transformers have a voltage rating of up to 34.5 kV on the primary side and up to 15 kV on the secondary side. The regulation applies to pad, pole, substation, and submersible transformers; and applies to newly purchased as well as repaired / refurbished transformers.

Test Standard

The NOM-002-SEDE-2014 refers to a National Mexican Norm, NMX-J-169-ANCE-2004. The local norm has been found to refer to the IEC test method family in the 2013 SEAD analysis (SEAD, 2013).

Energy Efficient Distribution Transformer Policies

Mexico began regulating distribution transformers more than three decades ago when it enacted NOM-J116 in 1977. The latest version of the Norma Mexicana (NOM) was updated in 2014 when NOM-002-SEDE-2014 was revised to update several aspects of the standard. The new version of the document, NOM-002-SEDE-2014, was published in August 2014. More information about Mexico standards and labeling program is available at: http://www.conuee.gob.mx/wb/.

Table 36 and Table 37 show the MEPS for Mexico, given in terms of efficiency and maximum losses respectively, tested at 80% load. Within each table, the requirements are divided into three groups, based on the primary voltage.

Table 36 - Minimum Efficiency Levels for Liquid-Filled Distribution Transformers in Mexico

Type	kVA	Up to 95 kV BIL (Up to 15 kV)	Up to 150 kV BIL (Up to 25 kV)	Up to 200 kV BIL (Up to 34.5 kV)
		% efficiency*	% efficiency	% efficiency
Single-Phase	10	98.61	98.49	98.28
	15	98.75	98.63	98.43
	25	98.90	98.79	98.63
	37.5	98.99	98.90	98.75
	50	99.08	98.99	98.86
	75	99.21	99.12	99.00
	100	99.26	99.16	99.06
	167	99.30	99.21	99.13
Three-Phase	15	98.32	98.18	98.03
	30	98.62	98.50	98.35
	45	98.72	98.60	98.48
	75	98.86	98.75	98.64
	112.5	98.95	98.85	98.76
	150	99.03	98.94	98.86
	225	99.06	98.96	98.87
	300	99.11	99.02	98.92
	500	99.20	99.11	99.03

*Note: Efficiency is defined at 80% load

Table 37 - Maximum Losses for Liquid-Type Distribution Transformers in Mexico

Type	kVA	Up to 95 kV BIL (Up to 15 kV)	Up to 150 kV BIL (Up to 25 kV)	Up to 200 kV BIL (Up to 34.5 kV)
		Max Total Losses (W)*	Max Total Losses (W)	Max Total Losses (W)
Single-Phase	10	113	123	140
	15	152	167	191
	25	222	245	278
	37.5	306	334	380
	50	371	408	461
	75	478	533	606
	100	596	678	759
	167	942	1,064	1,173
Three-Phase	15	205	222	241
	30	336	365	403
	45	467	511	556
	75	692	759	827
	112.5	955	1,047	1,130
	150	1,175	1,286	1,384
	225	1,708	1,892	2,057
	300	2,155	2,375	2,620
	500	3,226	3,592	3,918

*Note: Maximum losses defined at 80% load

Republic of Peru

Scope of Coverage

Efficiency requirements for liquid-type distribution transformers are defined as voluntary requirements as part of the "Norma Técnica Peruana" NTP 370.002. The NTP covers single-phase liquid-filled distribution transformers from 5 to 50kVA and three-phase liquid-filled distribution transformers from 15kVA to 630kVA.

Test Standard

The test standard defined in NTP 370.002 is based on the family of international test standards for transformers, IEC 60076-1.

Energy Efficient Distribution Transformer Policies

Table 38 and Table 39 present the efficiency requirements defined in the NTP. More information about the NTP standards is available at: http://www.minem.gob.pe/.

Table 38 - Voluntary Maximum Losses for Single-Phase Liquid-Filled Distribution Transformers in Peru

Capacity (kVA)	Low Voltage (60Hz)		Medium Voltage (60 Hz)	
	Max Core Loss (W)	Max Coil Loss (W)	Max Core Loss (W)	Max Coil Loss (W)
5	49	142	62	144
10	68	211	81	233
15	86	278	101	319
20	103	342	125	388
25	120	410	150	469
37.5	165	608	196	629
50	199	776	240	793

Table 39 - Voluntary Maximum Losses for Three-Phase Liquid-Filled Distribution Transformers in Peru

Capacity (kVA)	Low Voltage (60Hz)		Medium Voltage (60Hz)	
	Max Core Loss (W)	Max Coil Loss (W)	Max Core Loss (W)	Max Coil Loss (W)
15	106	451	135	452
25	146	595	174	653
37.5	188	866	210	900
50	232	1,120	248	1,135
75	300	1,521	327	1,551
100	374	1,920	417	1,975
125	442	2,239	483	2,317
160	537	2,775	571	2,843
200	606	3,375	648	3,257
250	734	3,804	771	3,737
315	837	4,533	866	4,500
400	968	5,550	1,050	5,429
500	1,179	6,540	1,221	6,464
630	1,411	8,136	1,486	8,144

United States of America

Scope of Coverage

Distribution transformers that are subject to regulatory requirements in the United States include transformers that:
(1) Have an input voltage of 34.5 kV or less;
(2) Has an output voltage of 600 V or less;
(3) Is rated for operation at a frequency of 60 Hz; and
(4) Has a capacity of 10 kVA to 2500 kVA for liquid-immersed units and 15 kVA to 2500 kVA for dry-type units;
The regulation does not include a transformer that is an— (i) Autotransformer; (ii) Drive (isolation) transformer; (iii) Grounding transformer; (iv) Machine-tool (control) transformer; (v) Nonventilated transformer; (vi) Rectifier transformer; (vii) Regulating transformer; (viii) Sealed transformer; (ix) Special-impedance transformer; (x) Testing transformer; (xi) Transformer with tap range of 20 percent or more; (xii) Uninterruptible power supply transformer; or (xiii) Welding transformer.

Test Standard

As reported in (SEAD, 2013b), DOE adopted its test standard for measuring the efficiency of distribution transformers in April 2006. DOE's test standard is based on the test standard contained in NEMA TP 2-1998 and IEEE Standards C57.12.90-1999 and C57.12.91-2001. DOE's test standard determines the percent energy-efficiency of distribution transformers through the measurement of no-load and load losses, and specifies the temperature, current, voltage, extent of distortion in voltage waveform, and direct current resistance of the windings. The test standard also provides the equation for calculating energy-efficiency.

Energy Efficient Distribution Transformer Policies

As reported in (SEAD, 2013a), the United States (U.S.) has been working on energy-efficiency for distribution transformers for over 20 years. More information on the U.S. appliance and equipment standards program is available at: http://energy.gov/eere/buildings/appliance-and-equipment-standards-program.

Starting with the Energy Policy Act of 1992, DOE initiated a process to review and establish energy conservation standards for distribution transformers. In parallel with that effort, the National Electrical Manufacturer's Association (NEMA) in the U.S. first published its voluntary standard, NEMA TP-1 in 1996 and was subsequently updated in 2002 (NEMA, 2002), covering the following distribution transformers:

- Liquid-filled distribution transformers, single and three-phase
- Dry-type, low-voltage, single and three phase
- Dry-type, medium-voltage, single and three-phase

In September 2000, DOE initiated its work to develop energy conservation regulatory standards for liquid-filled (and dry-type) distribution transformers. In October 2007, DOE completed its analysis on liquid-filled and medium-voltage dry-type distribution transformers, and published the Final Rule for Energy Conservation Standards for Distribution Transformers (USDOE, 2007a). This regulation stipulates that covered distribution transformers manufactured or imported into the United States after January 1, 2010 had to have efficiencies that were no less than the specified efficiency values at 50% of rated load.

In parallel with DOE working on these regulations, the US Congress passed the Energy Policy Act of 2005 which specified that the efficiency of all low-voltage dry-type transformers "manufactured on or after January 1, 2007, shall be the Class I Efficiency Levels for distribution transformers specified in table 4-2 of the 'Guide for Determining Energy Efficiency for Distribution Transformers' published by the National Electrical Manufacturers Association (NEMA TP-1-2002)." In adopting this language, Congress established the NEMA TP-1 -2002 requirements as mandatory efficiency requirements for low-voltage dry-type distribution transformers.

In 2011, DOE initiated work on reviewing its regulations on distribution transformers, including all three groups - liquid-filled, low-voltage dry-type and medium-voltage dry-type transformers. And in April 2013, DOE published updated efficiency requirements that will become effective in January 2016 (USDOE, 2013). Table 40 through Table 43 present the regulations for liquid-filled, low-voltage dry-type, medium-voltage dry-type and three phase, medium-voltage dry-type transformers, both the existing 2010 regulation and upcoming 2016 regulation.

Table 40 - MEPS for Liquid-type Distribution Transformers in the U.S.

	Single-Phase			Three-Phase	
kVA	% Efficiency 2010	% Efficiency 2016	kVA	% Efficiency 2010	% Efficiency 2016
10	98.62	98.70	15	98.36	98.65
15	98.76	98.82	30	98.62	98.83
25	98.91	98.95	45	98.76	98.92
37.5	99.01	99.05	75	98.91	99.03
50	99.08	99.11	112.5	99.01	99.11
75	99.17	99.19	150	99.08	99.16
100	99.23	99.25	225	99.17	99.23
167	99.25	99.33	300	99.23	99.27
250	99.32	99.39	500	99.25	99.35
333	99.36	99.43	750	99.32	99.4
500	99.42	99.49	1,000	99.36	99.43
667	99.46	99.52	1,500	99.42	99.48
833	99.49	99.55	2,000	99.46	99.51
-	-	-	2,500	99.49	99.53

Table 41 - MEPS for Low-Voltage Dry-Type Distribution Transformers in the U.S.

kVA	Single-Phase		kVA	Three-Phase	
	% Efficiency 2007	% Efficiency 2016		% Efficiency 2007	% Efficiency 2016
25	98.0	98.00	30	97.5	98.23
37.5	98.2	98.20	45	97.7	98.40
50	98.3	98.30	75	98.0	98.60
75	98.5	98.50	112.5	98.2	98.74
100	98.6	98.60	150	98.3	98.83
167	98.7	98.70	225	98.5	98.94
250	98.8	98.80	300	98.6	99.02
333	98.9	98.90	500	98.7	99.14
-	-	-	750	98.8	99.23
-	-	-	1,000	98.9	99.28

* All efficiency levels in this table are measured at 35% load.

Table 42 - MEPS for Single Phase, Medium-Voltage Dry-Type Transformers in the U.S.

kVA	20-45 kV BIL		46-95 kV BIL		≥96 kV BIL	
	% Efficiency 2010	% Efficiency 2016	% Efficiency 2010	% Efficiency 2016	% Efficiency 2010	% Efficiency 2016
15	98.10	98.10	97.86	97.86	-	-
25	98.33	98.33	98.12	98.12	-	-
37.5	98.49	98.49	98.30	98.30	-	-
50	98.60	98.60	98.42	98.42	-	-
75	98.73	98.73	98.57	98.57	98.53	98.53
100	98.82	98.82	98.67	98.67	98.63	98.63
167	98.96	98.96	98.83	98.83	98.80	98.80
250	99.07	99.07	98.95	98.95	98.91	98.91
333	99.14	99.14	99.03	99.03	98.99	98.99
500	99.22	99.22	99.12	99.12	99.09	99.09
667	99.27	99.27	99.18	99.18	99.15	99.15
833	99.31	99.31	99.23	99.23	99.20	99.20

* All efficiency levels in this table are measured at 50% load.

Table 43 - MEPS for Three Phase, Medium-Voltage Dry-Type Transformers in the U.S.

kVA	20-45 kV		46-95 kV		≥96 kV BIL	
	% Efficiency 2010	% Efficiency 2016	% Efficiency 2010	% Efficiency 2016	% Efficiency 2010	% Efficiency 2016
15	97.50	97.50	97.18	97.18	-	-
30	97.90	97.90	97.63	97.63	-	-
45	98.10	98.10	97.86	97.86	-	-
75	98.33	98.33	98.12	98.13	-	-
112.5	98.49	98.52	98.3	98.36	-	-
150	98.60	98.65	98.42	98.51	-	-
225	98.73	98.82	98.57	98.69	98.53	98.57
300	98.82	98.93	98.67	98.81	98.63	98.69
500	98.96	99.09	98.83	98.99	98.80	98.89
750	99.07	99.21	98.95	99.12	98.91	99.02
1,000	99.14	99.28	99.03	99.20	98.99	99.11
1,500	99.22	99.37	99.12	99.30	99.09	99.21
2,000	99.27	99.43	99.18	99.36	99.15	99.28
2,500	99.31	99.47	99.23	99.41	99.20	99.33

* All efficiency levels in this table are measured at 50% load.

The U.S. Environmental Protection Agency (EPA) and DOE managed a program called "Energy Star Distribution Transformers" to overcome market barriers preventing industrial/commercial customers and utilities from purchasing more energy-efficient low-voltage dry-type distribution transformers. The minimum efficiency that a transformer had to meet or exceed to be classified as an Energy Star transformer was the same as NEMA's TP 1. The Energy Star Transformers program was suspended on May 1, 2007 because EPACT 2005 established NEMA TP 1 as the national MEPS level for low-voltage dry-type transformers. However, EPA has announced in 2014 that it was launching a process to develop a new Energy Star specification for medium-voltage liquid-filled distribution transformers. The first draft of specifications is under review by stakeholders and considers a new approach to define minimum efficiency requirements at different load factors (between 10% and 70%). This approach will allow for an increase optimization of transformers for their intended capacity factor, or load. As of March 2016, the requirements are still under development[5]. An image of the Energy Star label is given below:

Figure 14 - U.S. Energy Star Label

[5] More information available at: http://www.energystar.gov/products/spec/distribution_transformers_pd

Socialist Republic of Vietnam

Scope of Coverage

The national testing standards used to measure performance are called “Tiêu chuẩn Việt Nam“ (TCVN), which in English means “Viet Nam Standards”. Viet Nam’s regulation on distribution transformers is contained in TCVN 8525: 2010 (Distribution Transformers - the minimum energy efficiency and methods for determining energy efficiency). This standard establishes the MEPS and test standards of determining the energy efficiency for three-phase liquid-filled distribution transformers with nominal capacity from 25 to 2,500 kVA and nominal voltage up to 35 kV and frequency of 50Hz.

Test Standard

In TCVN 8525:2010, the regulation cross-references the loss measurement procedures adopted in the Vietnamese Standard TCVN 6306-1, which is harmonized with IEC 60076.

Energy Efficient Distribution Transformer Policies

In November 2011, the Ministry of Industry and Trade (MOIT) of Viet Nam adopted mandatory efficiency regulations for distribution transformers that entered into force on January 1, 2015 (MOIT, 2010). Table 44 presents the minimum efficiency requirement in TCVN 8525:2010. More information about Vietnam mandatory regulations is available at: http://www.moit.gov.vn/vn/Pages/Trangchu.aspx

Table 44 - Minimum Efficiency Requirements for Three-Phase Liquid-Type Transformers for Viet Nam

Capacity	Minimum Efficiency
kVA	%
25	98.28
32	98.34
50	98.50
63	98.62
100	98.76
125	98.80
160	98.87
200	98.94
250	98.98
315	99.04
400	99.08
500	99.13
630	99.17
750	99.21
800	99.22
1,000	99.27
1,250	99.31
1,500	99.35
1,600	99.36
2,000	99.39
2,500	99.40

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Annex I

Annex Table I - Comparison of General Test Condition Requirements under IEC and IEEE Standards

No.	Item	IEC		IEEE	
	Standard No. & Clause	**60076-1**	**Clause**	**C57.12.00**	**Clause**
1	**Test Source**				
	Voltage Wave Shape	Total harmonic content not to exceed 5%	11.1.1	Harmonic content not addressed	
	Frequency	Within 1%	11.1.1	Within 0.5%	9.4.
	Phase Symmetry	<3% unbalance between Phases	11.1.1	Unbalanced not addressed	
2	**Accuracy**	Refers to 60060 & 60076-8	11.1.1	Requirements described in details	9.4
3	**Ref. Temp. for Losses**				
	No Load Losses	75C	11.1.1.b.1	20C	5.9
	Load Losses	75C	"	85C	5.9
4	**Frequency**	No mention		60Hz	5.2
5	**Loss Tolerance**				
	No Load	+15%	10	+10%	9.3
	Load Loss	+15%	10	-	
	Total Losses	+10%	10	+6%	9.3

Annex Table II - Comparison of No Load Loss Tests under IEC and IEEE Standards

No.	Item	IEC		IEEE	
	Standard No. & Clause	**60076-1**	**Clause**	**C57.12.00**	**Clause**
1	**No Load Test standard**	Described.	11.5		
2	**No Load Loss Correction**				
	For Voltage Wave Shape	Formula provided but different than IEEE formula	11.5		
	Maximum Waveform Correction	Max. difference in two voltmeter readings shall be less than 3%.	11.5		
	For Temperature	Test shall be performed at factory ambient temperature. No correction formula provided.	11.5		
3	**Reference Temperature for Losses**				
	No Load Losses	75C	11.1.1.b.1	20C	5.9
	Load Losses	75C	"	85C	5.9
4	**Test Frequency**	At rated frequency - no tolerance specified.	11.5		
5	**Loss Tolerance**				
	No Load	+15%	10	+10%	9.3
	Load Loss	+15%	10	-	
	Total Losses	+10%	10	+6%	9.3
	Exciting Current	+30% of design Value	10		

Annex Table III - Comparison of Load Loss Tests under IEC and IEEE Standards

No.	Item	IEC		IEEE	
	Standard No. & Clause	**60076-1**	**Clause**	**C57.12.00**	**Clause**
1	**Load Loss Test standard**	Described	11.4		
2	**Test (load) Current**	Minimum 50% of rated current	11.4		
3	**Resistance Test**				
	Requirement	Routine testing	11.1.2.2	Design test for 2,500 kVA & smaller distribution transformers	Table 18
	Method	Describes test conditions but not test standard	11.2		
4	**Reference Temperature for Losses**				
	No Load Losses	75C	11.1.1.b.1	20C	5.9
	Load Losses	75C	"	85C	5.9
5	**Test Frequency**	At rated frequency - no tolerance specified	11.4		
6	**Loss Tolerance**				
	No Load	+15%	10	+10%	9.3
	Load Loss	+15%	10	-	
	Total Losses	+10%	10	+6%	9.3

Annex Table IV - Comparison of Efficiency Calculation for Distribution Transformers under IEC and IEEE Standards

No.	Item	IEC		IEEE	
	Standard No. & Clause	**60076-1**	**Clause**	**C57.12.00**	**Clause**
1	**Rated kVA** (Power)	Input*	5.1.1	Output	5.4.1
	*Rated Power for Two-winding Transformer	Input = Output	3.4.6 & 5.1.1		
2	**Efficiency** @ Unity Power Factor	Input - Losses / Input		Output / Output + Losses	
3	**Ambient Temperature**	20C	4.2	30C	4.1.2.1
4	**Winding Temp. rise** @ rated kVA			65C	5.4.2
5	**Ref. Temp. for Losses**				
	No Load Losses	75C	11.1.1.b.1	20C	5.9
	Load Losses	75C	"	85C	5.9
6	**Frequency**	No mention		60	5.2
7	**Loss Tolerance**				
	No Load	+15%	10	+10%	9.3
	Load Loss	+15%	10	-	
	Total Losses	+10%	10	+6%	9.3